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O'Keefe et al.

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(54) **MEDICAL INSTRUMENTS FOR PERFORMING MINIMALLY-INVASIVE PROCEDURES**

(71) Applicant: **Lumendi Ltd.**, Buckinghamshire (GB)

(72) Inventors: **Jonathan O'Keefe**, North Attleboro, MA (US); **Jeffrey Cerier**, Franklin, MA (US); **Amos Cruz**, Wrentham, MA (US); **David Rezac**, Westborough, MA (US)

(73) Assignee: **Lumendi Ltd.**, Maidenhead (GB)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **16/846,695**

(22) Filed: **Apr. 13, 2020**

(65) **Prior Publication Data**

US 2020/0305906 A1 Oct. 1, 2020

Related U.S. Application Data

(63) Continuation of application No. 15/298,605, filed on Oct. 20, 2016, now Pat. No. 10,617,438.

(Continued)

(51) **Int. Cl.**

A61B 17/29 (2006.01)
A61B 17/00 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***A61B 17/29*** (2013.01); ***A61B 17/00234*** (2013.01); ***A61B 17/282*** (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC A61B 17/00234; A61B 17/282; A61B 17/2841; A61B 17/29; A61B 17/2909;

(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,708,137 A 11/1987 Tsukagoshi
5,273,026 A 12/1993 Wilk

(Continued)

FOREIGN PATENT DOCUMENTS

CN 101849846 6/2013
CN 104586474 5/2015

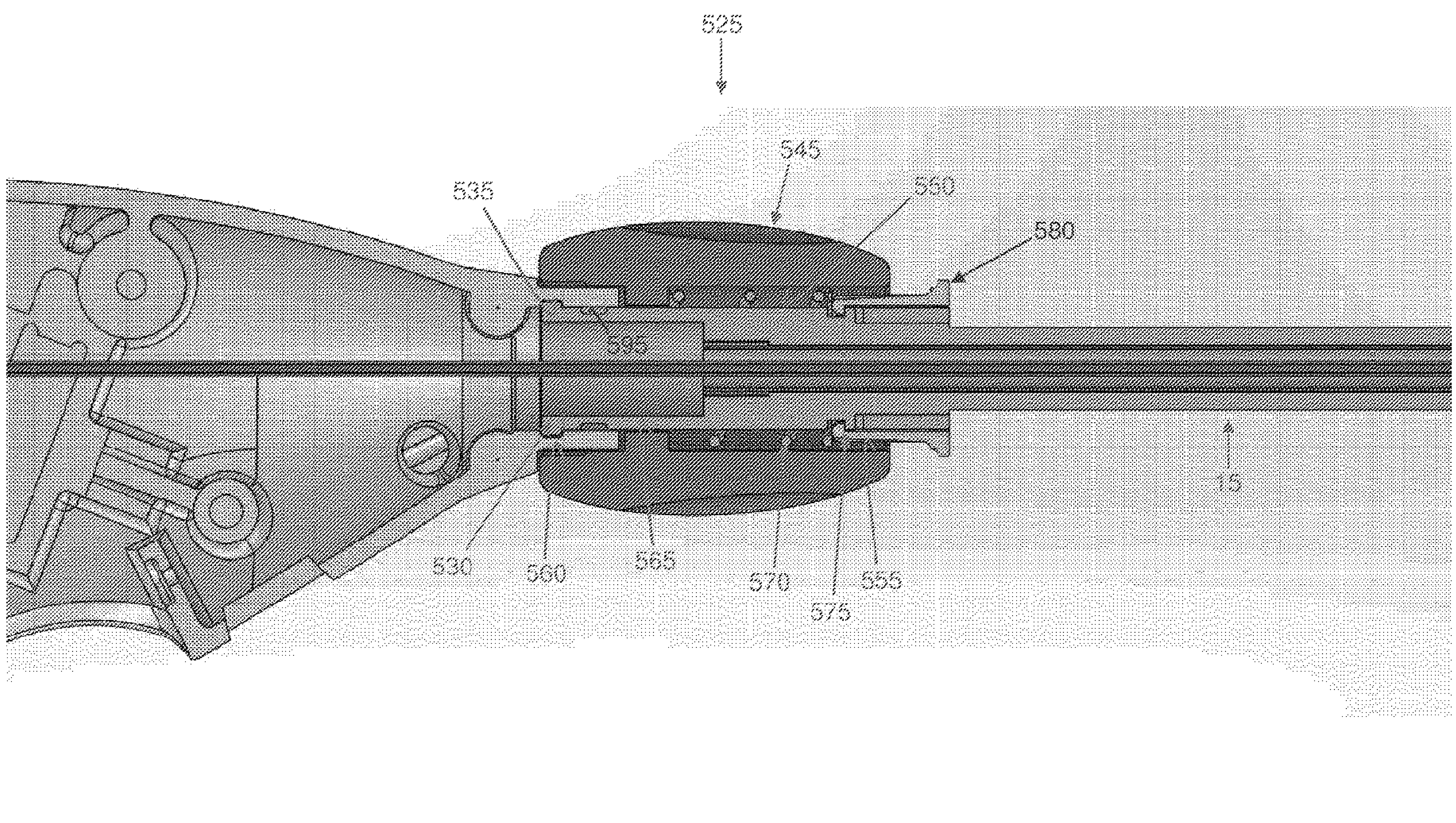
(Continued)

Primary Examiner — George J Ulsh
(74) *Attorney, Agent, or Firm* — Pandiscio & Pandiscio

(57) **ABSTRACT**

Apparatus for performing a minimally-invasive procedure, the apparatus comprising: a tool comprising: a shaft having a distal end and a proximal end; a handle attached to the proximal end of the shaft; and an end effector attached to the distal end of the shaft; wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine; wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends; wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated.

24 Claims, 70 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/400,759, filed on Sep. 28, 2016, provisional application No. 62/244,026, filed on Oct. 20, 2015.

(51) **Int. Cl.**
A61B 17/28 (2006.01)
A61B 90/50 (2016.01)

(52) **U.S. Cl.**
CPC ***A61B 17/2909*** (2013.01); *A61B 17/2841* (2013.01); *A61B 90/50* (2016.02); *A61B 2017/0046* (2013.01); *A61B 2017/00305* (2013.01); *A61B 2017/00309* (2013.01); *A61B 2017/00323* (2013.01); *A61B 2017/00353* (2013.01); *A61B 2017/00367* (2013.01); *A61B 2017/00473* (2013.01); *A61B 2017/00477* (2013.01); *A61B 2017/2905* (2013.01); *A61B 2017/2908* (2013.01); *A61B 2017/2925* (2013.01); *A61B 2017/2932* (2013.01)

(58) **Field of Classification Search**
CPC A61B 2017/00305; A61B 2017/00309; A61B 2017/00323; A61B 2017/00353; A61B 2017/00367; A61B 2017/0046; A61B 2017/00473; A61B 2017/00477; A61B 2017/2905; A61B 2017/2908; A61B 2017/2925; A61B 2017/2932; A61B 90/50
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,318,528	A	6/1994	Heaven et al.	
5,405,344	A	4/1995	Williamson et al.	
5,419,310	A	5/1995	Frassica et al.	
5,439,478	A	8/1995	Palmer	
5,454,827	A	10/1995	Aust et al.	
5,483,951	A	1/1996	Frassica et al.	
5,618,294	A	4/1997	Aust et al.	
5,643,294	A	7/1997	Tovey et al.	
5,702,408	A	12/1997	Wales et al.	
5,704,534	A	1/1998	Huitema et al.	
5,766,196	A	6/1998	Griffiths	
5,782,834	A	7/1998	Lucey et al.	
5,797,959	A	8/1998	Castro et al.	
5,836,960	A	11/1998	Kolesa et al.	
5,938,678	A	8/1999	Zirps et al.	
6,201,407	B1	3/2001	Kapusta et al.	
6,210,407	B1	4/2001	Webster	
6,350,231	B1	2/2002	Ailinger et al.	
6,569,105	B1	5/2003	Kortenbach et al.	
6,790,173	B2	9/2004	Saadat et al.	
7,090,683	B2	8/2006	Brock et al.	
7,125,408	B2	10/2006	Okada	
7,147,650	B2	12/2006	Lee	
7,169,141	B2	1/2007	Brock et al.	
7,214,230	B2	5/2007	Brock et al.	
7,338,513	B2	3/2008	Lee et al.	
7,364,582	B2	4/2008	Lee	
7,371,210	B2	5/2008	Brock et al.	
D583,051	S	12/2008	Lee et al.	
7,615,067	B2	11/2009	Lee et al.	
7,618,416	B2	11/2009	Ono et al.	
7,648,519	B2	1/2010	Lee et al.	
7,686,826	B2	3/2010	Lee et al.	
7,708,758	B2	5/2010	Lee et al.	
7,842,028	B2	11/2010	Lee	
D631,155	S	1/2011	Peine et al.	
D640,789	S	6/2011	Peine et al.	
8,016,825	B2	9/2011	Okada	
8,029,531	B2	10/2011	Lee et al.	
8,048,073	B2	11/2011	Nakamura et al.	
8,083,765	B2	12/2011	Lee et al.	
8,105,350	B2	1/2012	Lee et al.	
8,187,271	B2	5/2012	Yahagi et al.	
8,221,450	B2	7/2012	Lee et al.	
8,257,386	B2	9/2012	Lee et al.	
8,372,071	B2	2/2013	Machiya et al.	
8,409,175	B2	4/2013	Lee et al.	
8,409,245	B2	4/2013	Lee	
8,579,894	B2	11/2013	Falkenstein et al.	
8,679,097	B2	3/2014	Jorgensen et al.	
8,709,037	B2	4/2014	Lee et al.	
8,926,597	B2	1/2015	Lee	
9,138,283	B2	9/2015	Wake	
9,168,050	B1	10/2015	Peine et al.	
9,301,800	B2	4/2016	Suzuki et al.	
9,387,034	B2	7/2016	Okada	
9,427,256	B2	8/2016	Lee	
9,832,980	B2	12/2017	Kovarik et al.	
9,901,245	B2	2/2018	Kovarik et al.	
9,962,179	B2	5/2018	Castro et al.	
10,188,372	B2	1/2019	Lee	
10,226,266	B2	3/2019	Kovarik et al.	
2003/0135204	A1	7/2003	Lee et al.	
2004/0210284	A1	10/2004	Okada	
2005/0072280	A1	4/2005	Ono et al.	
2005/0113827	A1	5/2005	Dumbauld et al.	
2006/0270969	A1	11/2006	Toyonaga et al.	
2006/0271079	A1	11/2006	Akiba et al.	
2007/0038213	A1	2/2007	Machiya et al.	
2008/0027429	A1	1/2008	Oyatsu	
2008/0045785	A1	2/2008	Oyatsu	
2008/0065116	A1	3/2008	Lee et al.	
2008/0188868	A1	8/2008	Weitzner et al.	
2008/0300462	A1	12/2008	Intoccia et al.	
2010/0168510	A1	7/2010	Rogers et al.	
2010/0234831	A1	9/2010	Hinman et al.	
2011/0009863	A1*	1/2011	Marczyk	A61B 18/1445 606/51
2011/0092963	A1	4/2011	Castro	
2011/0137123	A1	6/2011	Suzuki et al.	
2011/0152609	A1	6/2011	Trusty et al.	
2012/0150155	A1	6/2012	Kappel et al.	
2013/0012958	A1	1/2013	Marczyk et al.	
2013/0267936	A1	10/2013	Stroup et al.	
2013/0317375	A1	11/2013	Garcia et al.	
2014/0148803	A1	5/2014	Taylor	
2014/0188159	A1	7/2014	Steege	
2014/0207134	A1	7/2014	Wake	
2014/0288554	A1	9/2014	Okada	
2015/0025528	A1	1/2015	Arts	
2015/0066033	A1	3/2015	Jorgensen	
2015/0164524	A1*	6/2015	Malkowski	A61B 18/1445 606/205
2016/0353979	A1	12/2016	Hashizume et al.	
2017/0105746	A1	4/2017	O'Keefe et al.	
2017/0231701	A1	8/2017	Cohen et al.	
2018/0008805	A1	1/2018	Pleijers	
2018/0078249	A1	3/2018	Stoy et al.	
2020/0337791	A1	10/2020	Shelton, IV et al.	

FOREIGN PATENT DOCUMENTS

CN	103717147	9/2017
JP	2008-220972	9/2008
JP	2009-112538	5/2009
WO	WO2006094242	9/2006
WO	WO2017171560	10/2017

* cited by examiner

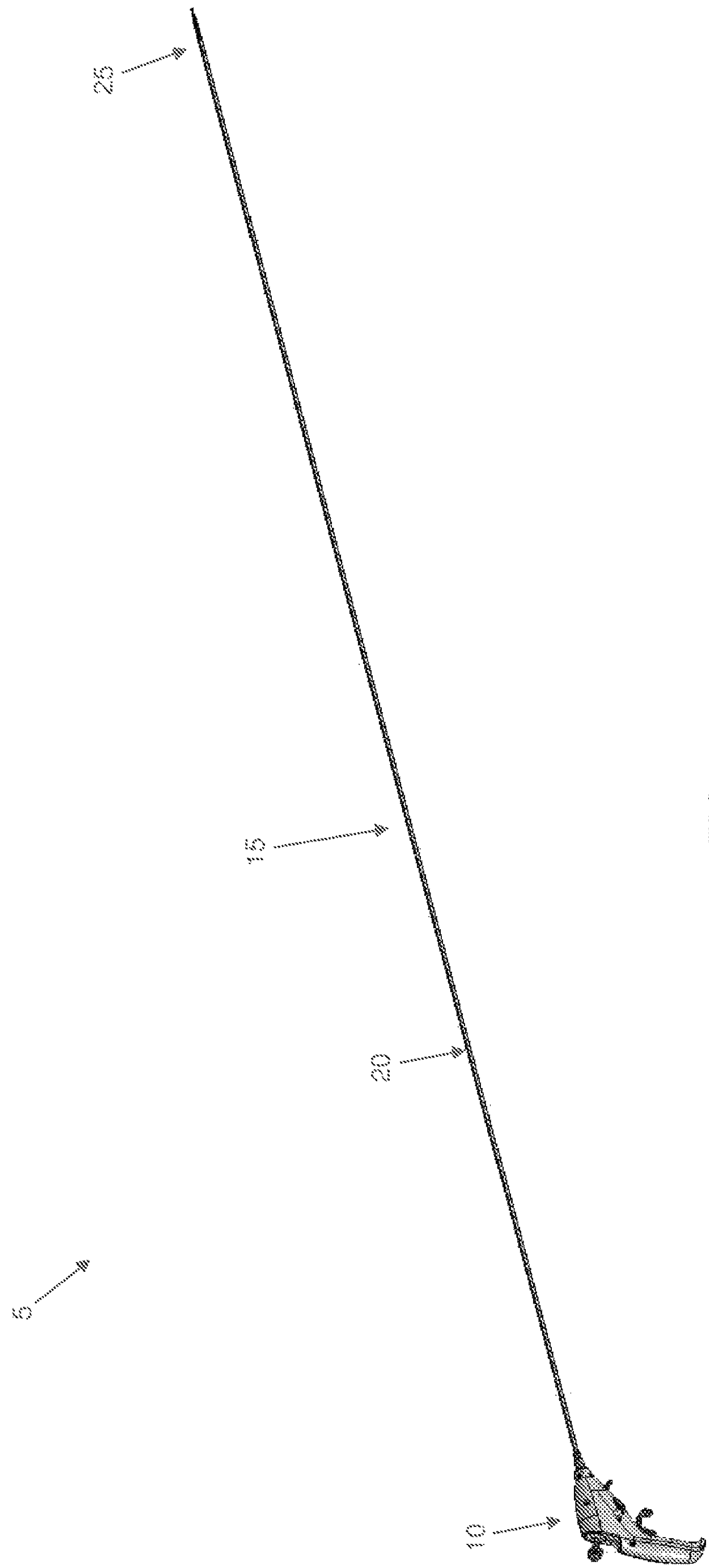


FIG. 1

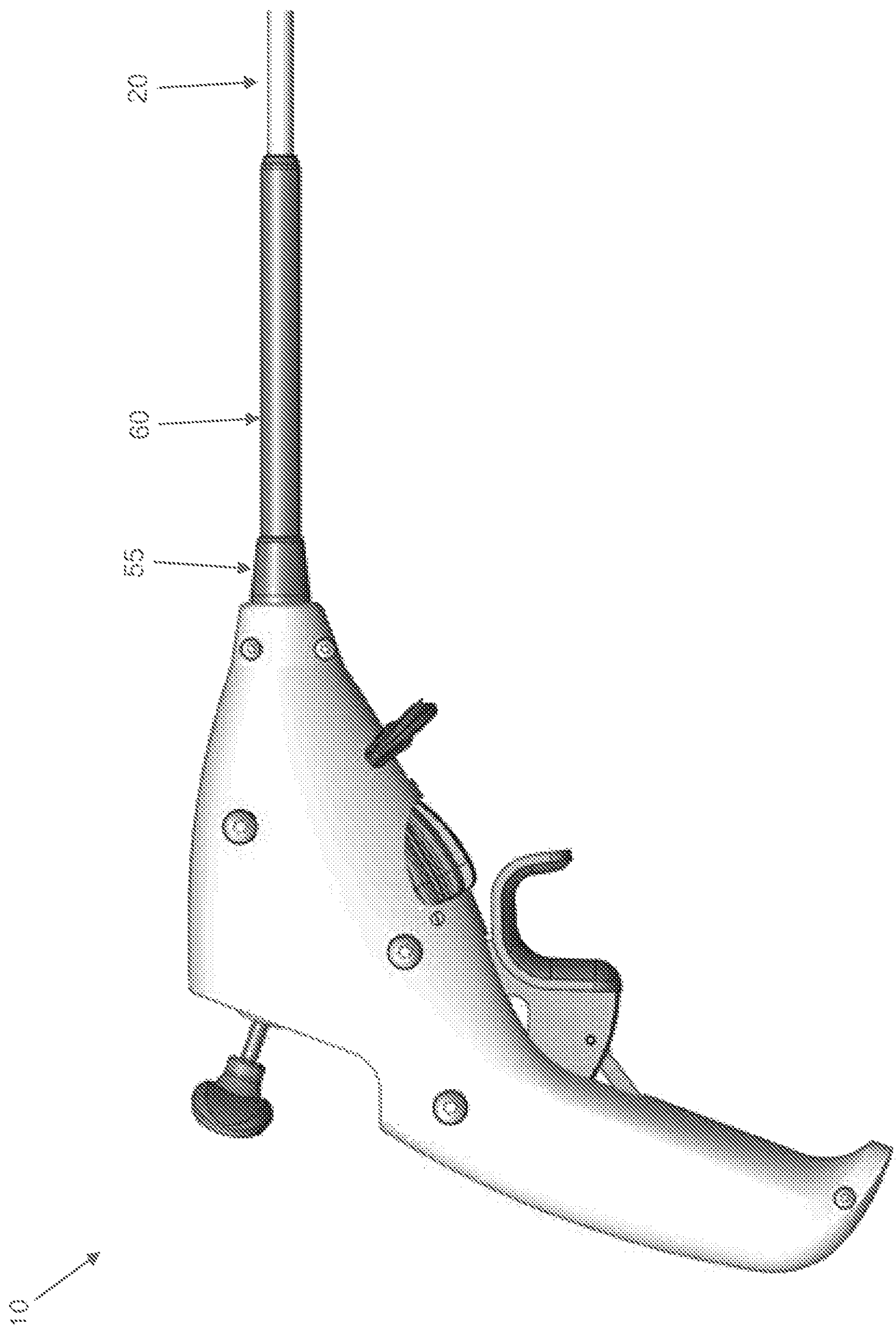
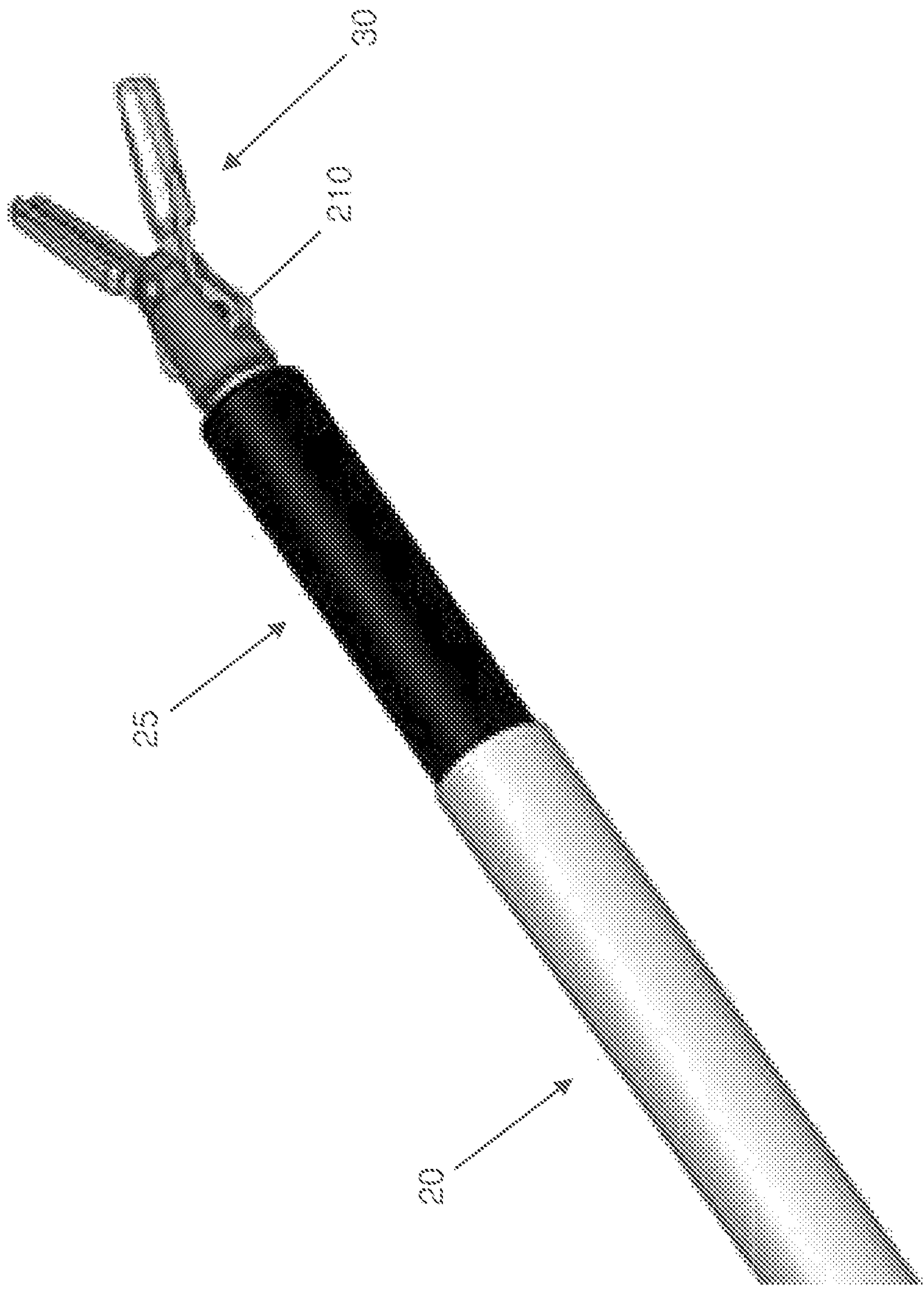


FIG. 1A



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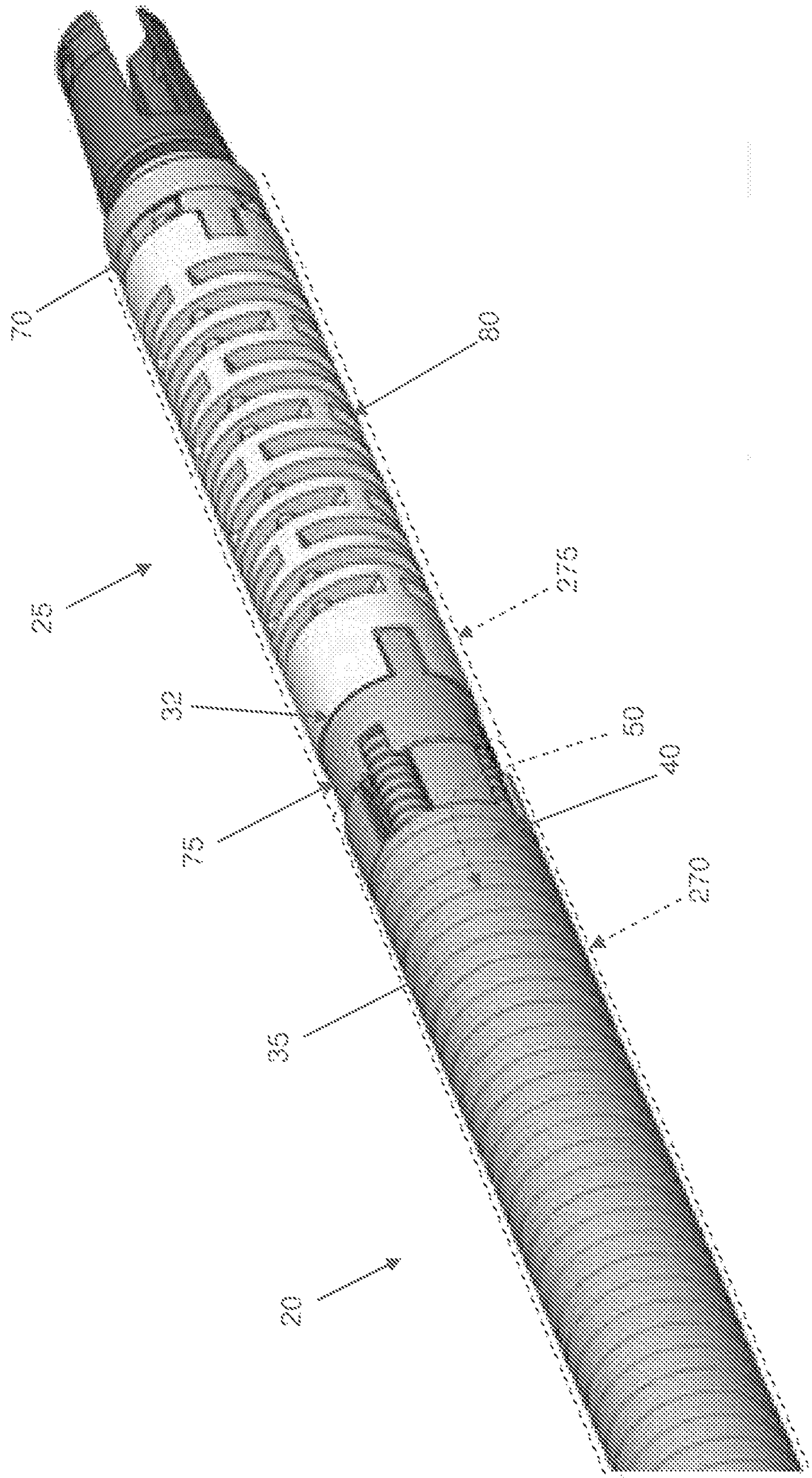
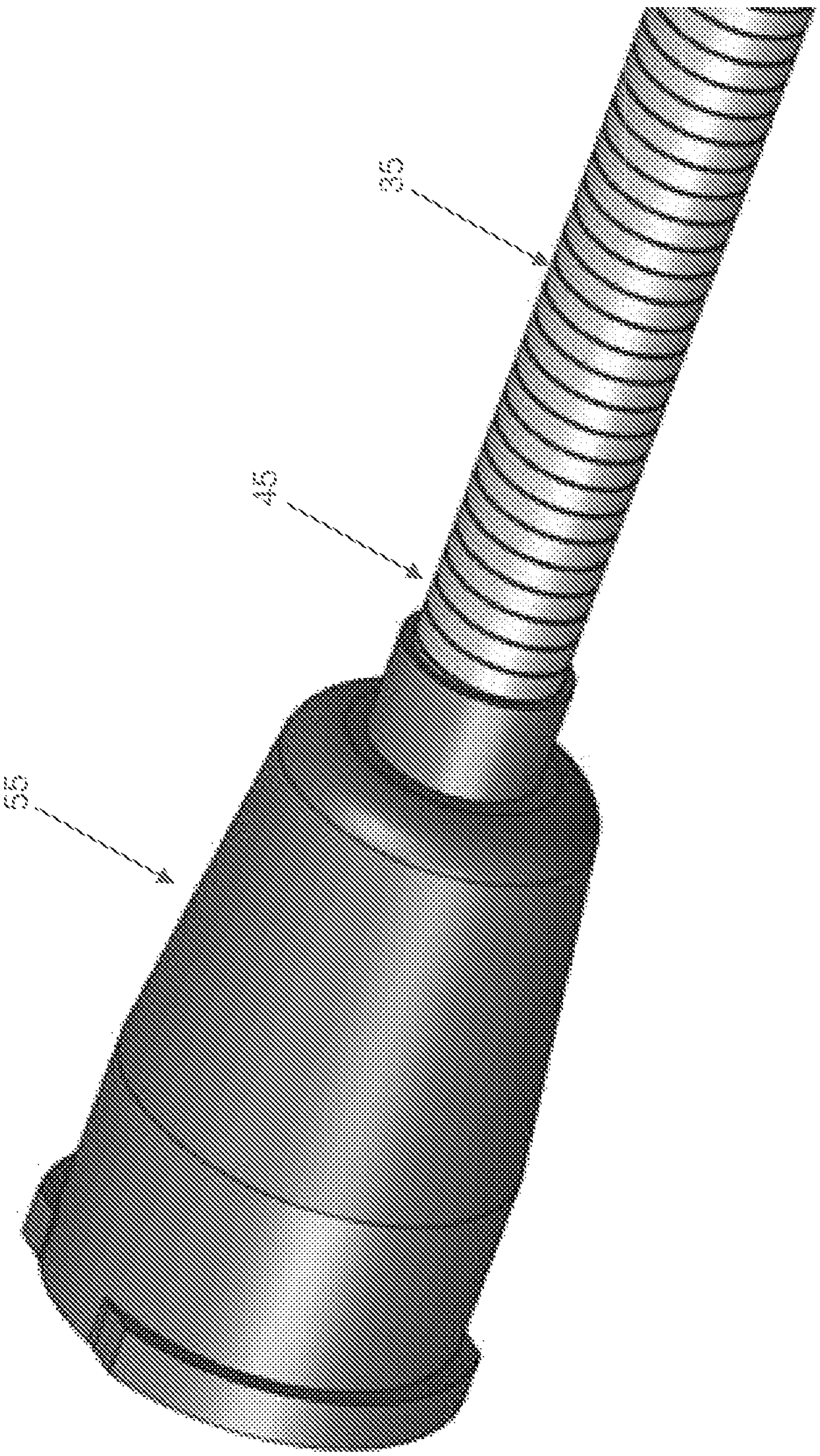


FIG. 2



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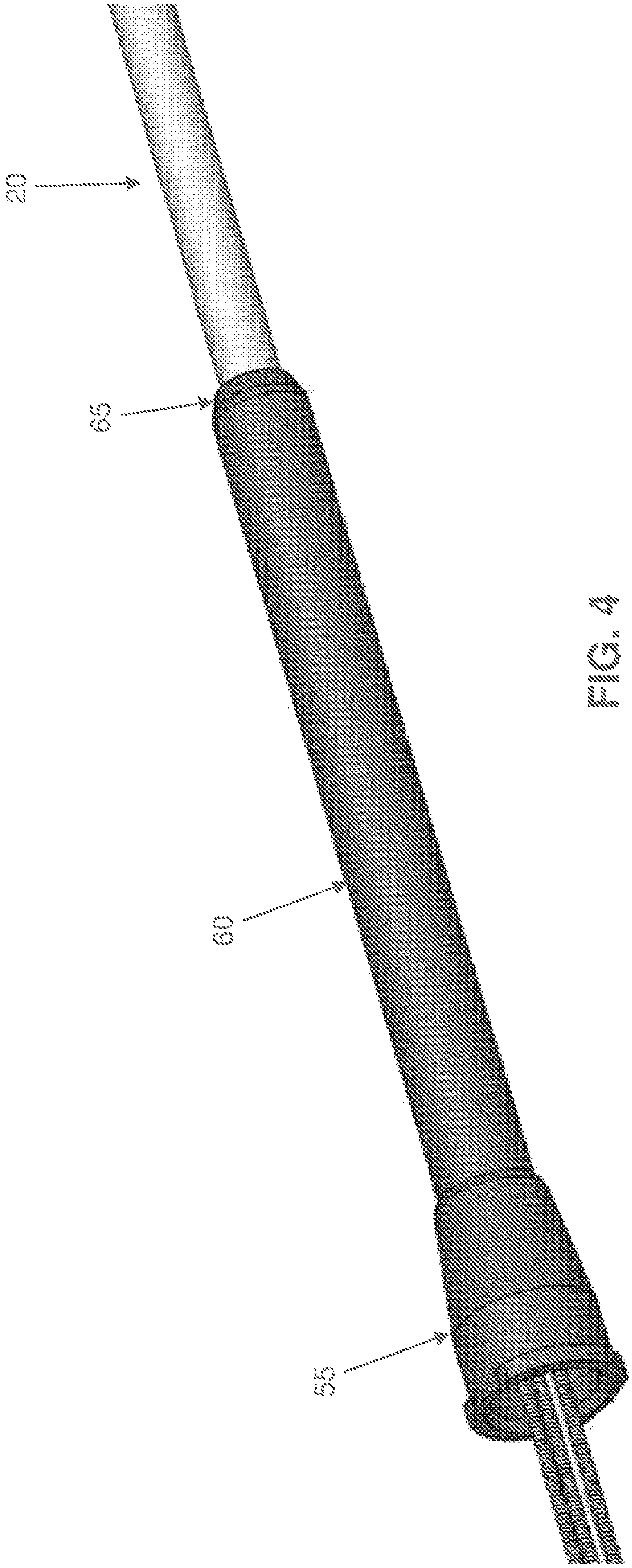

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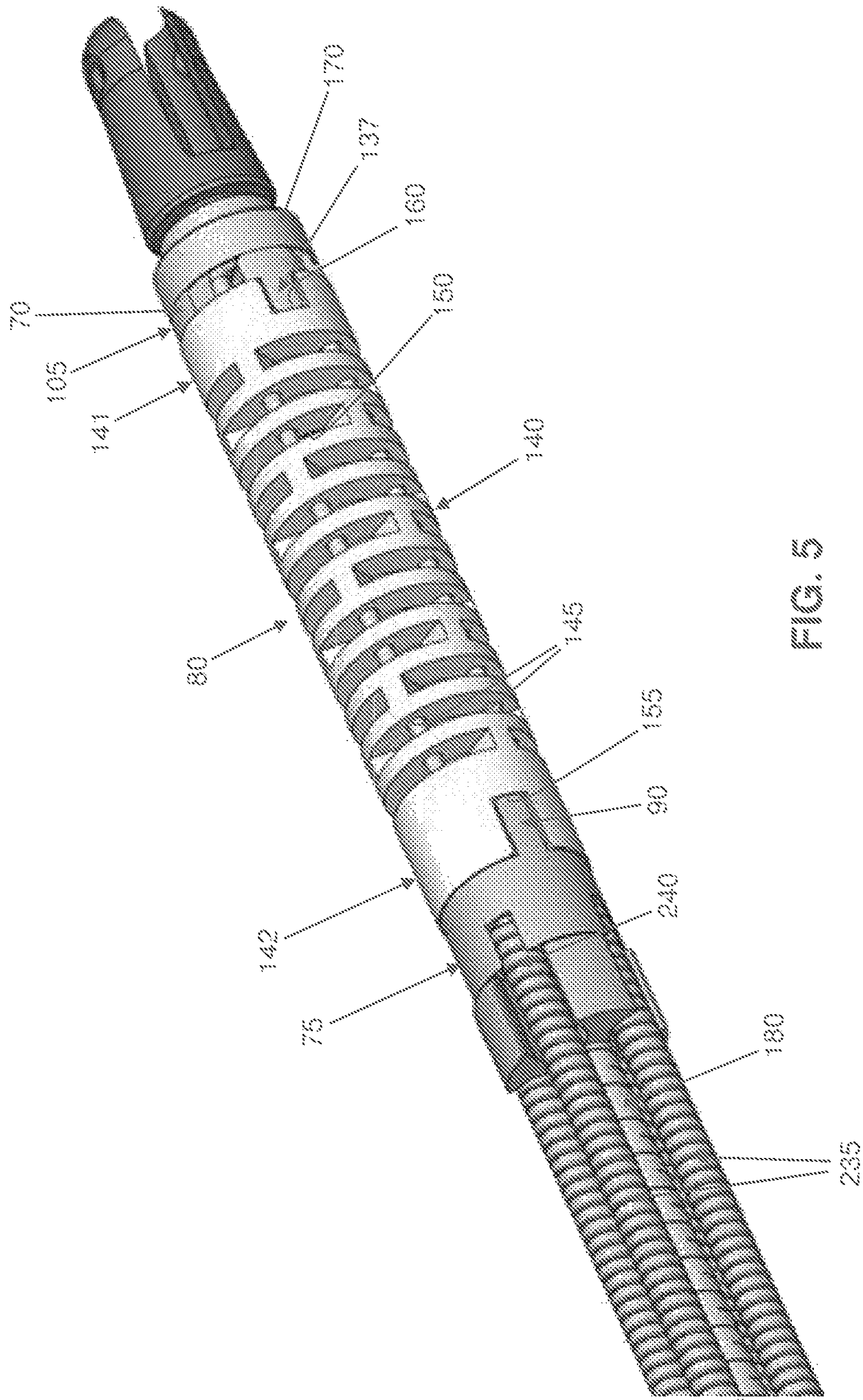

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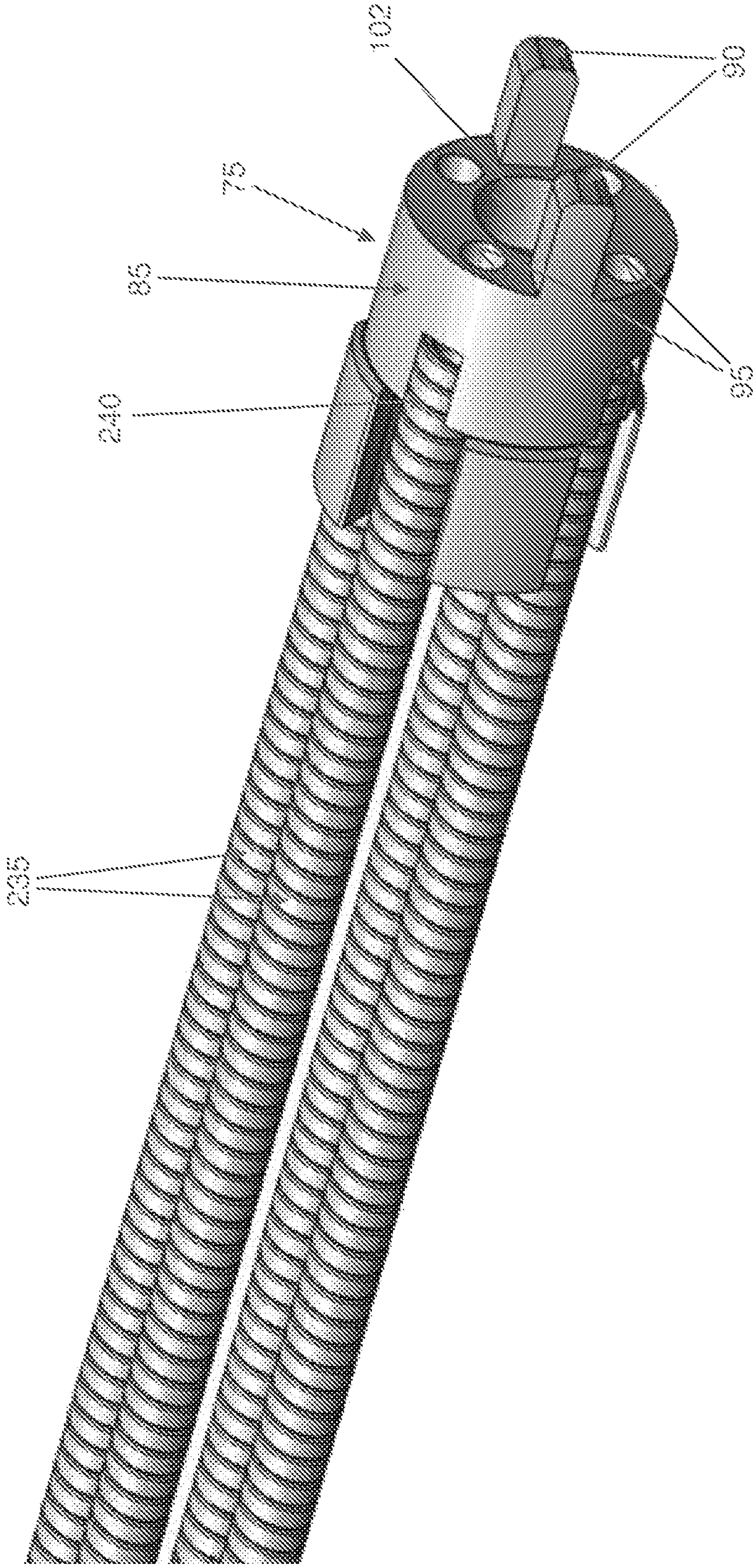

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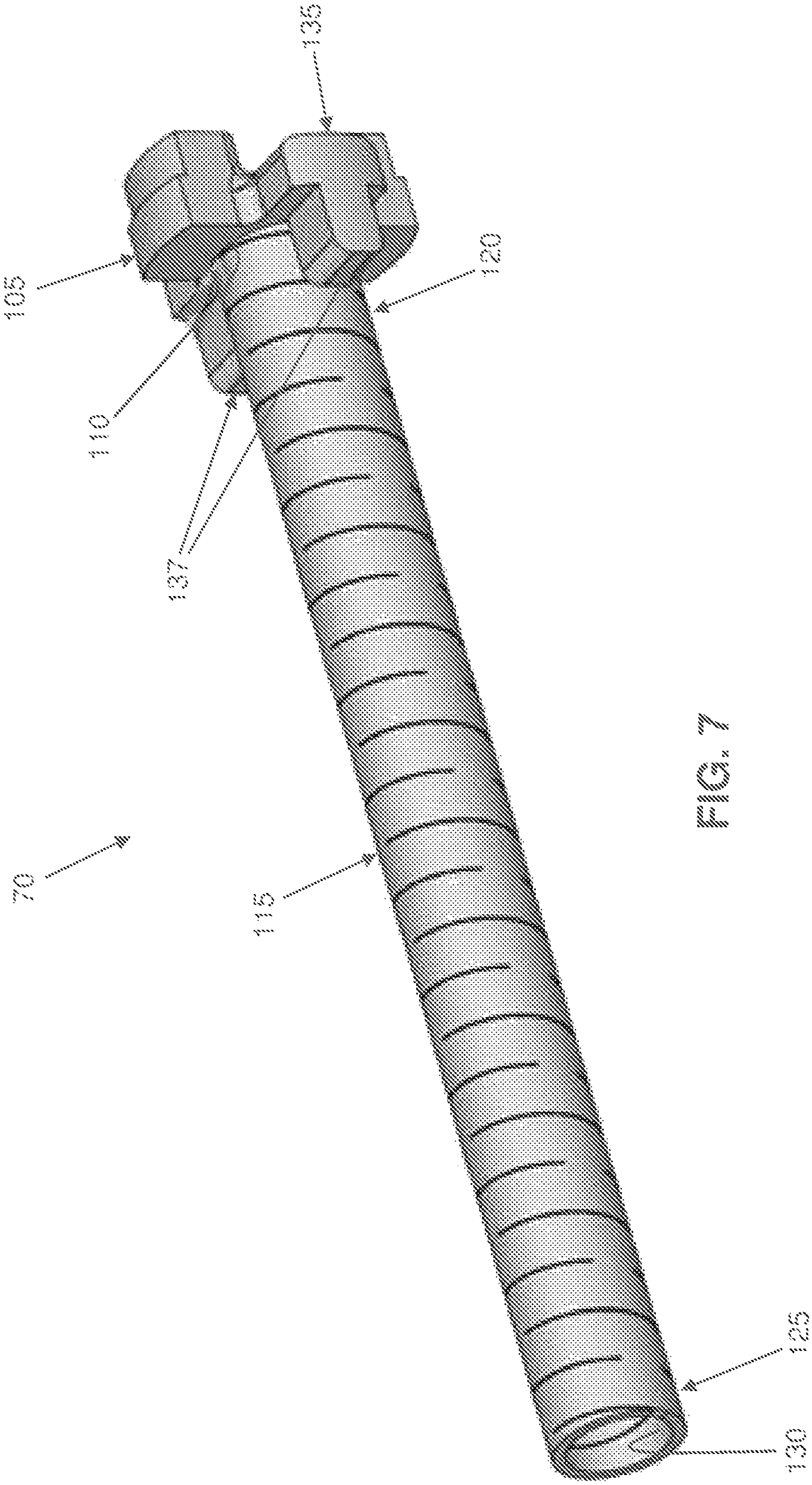

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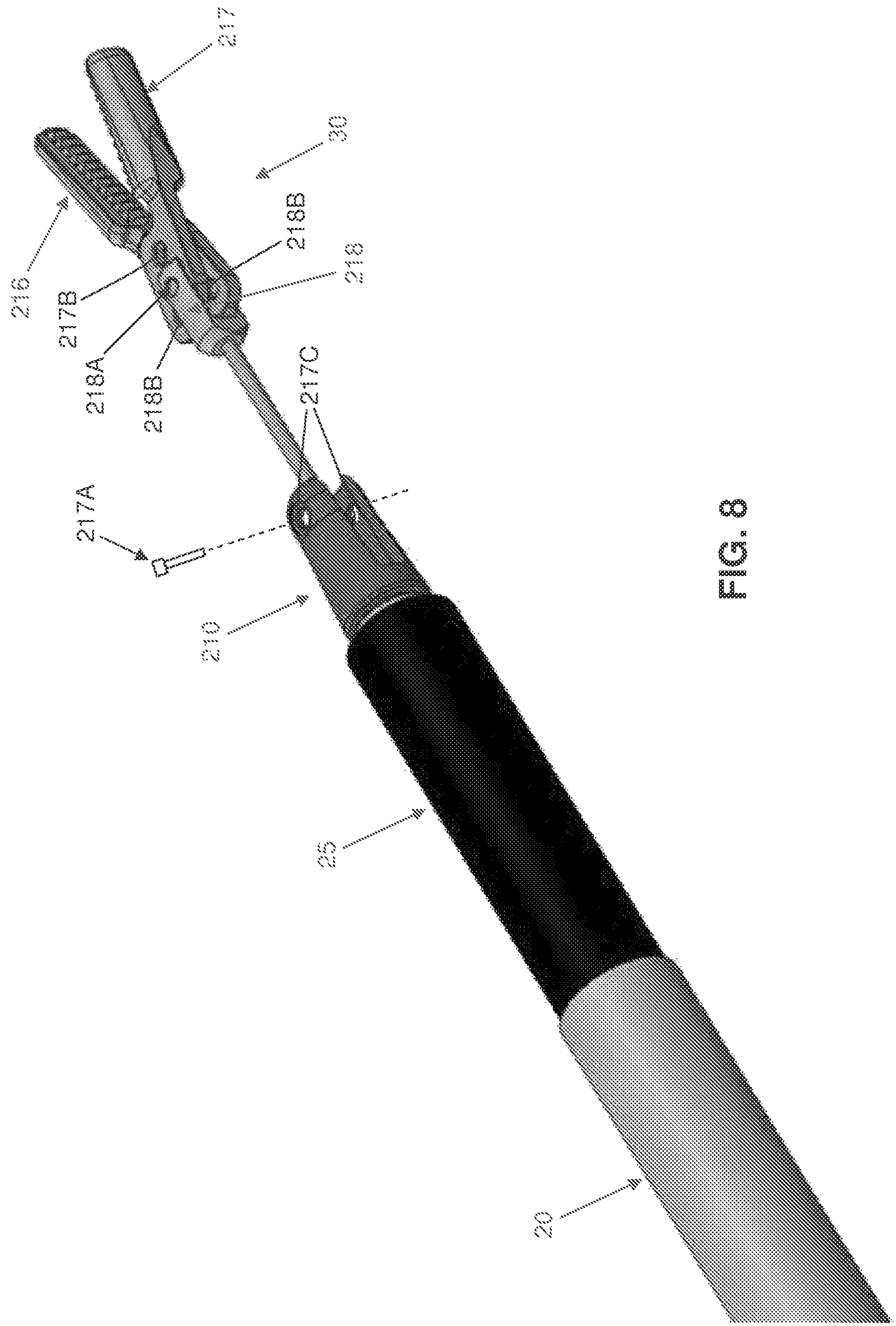

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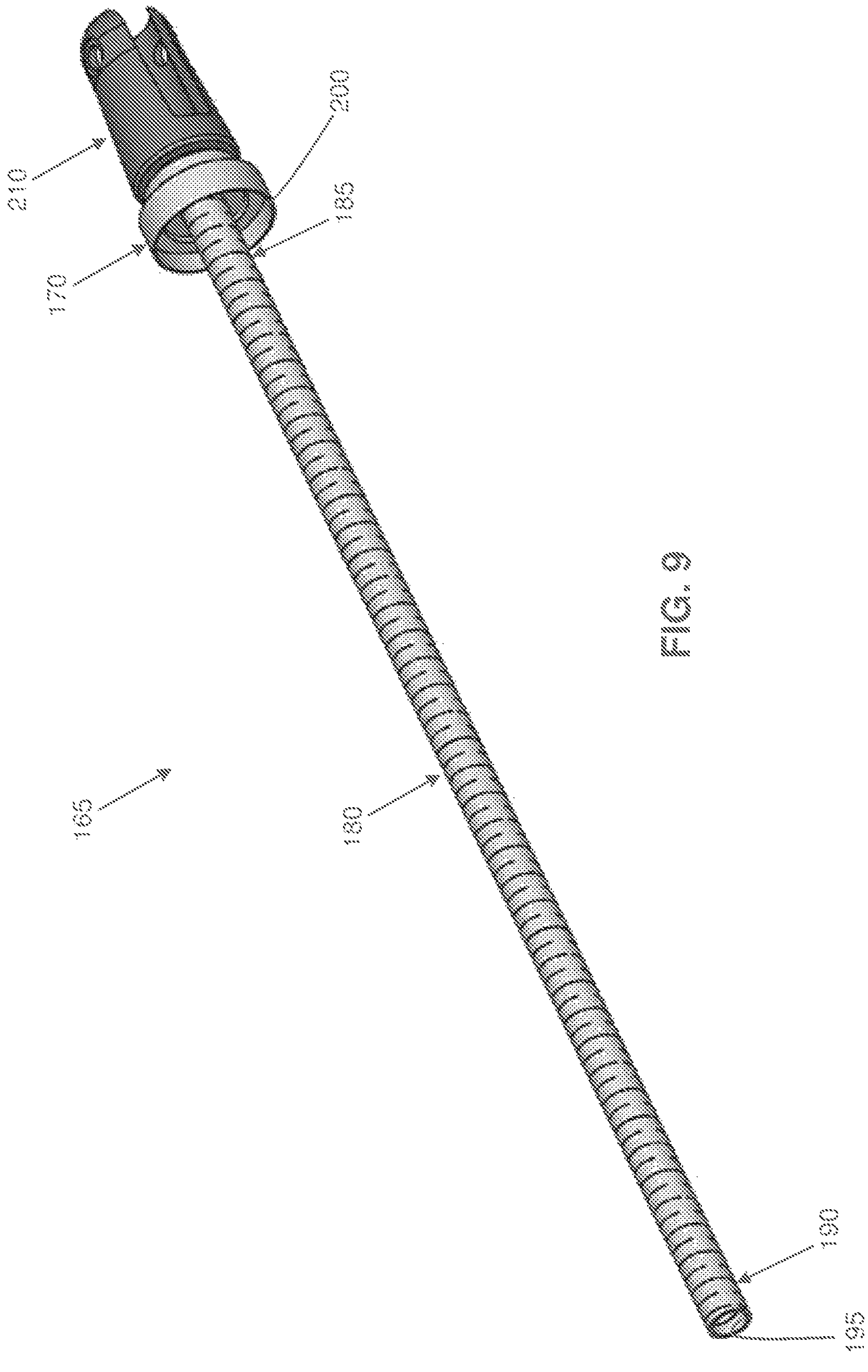


FIG. 9

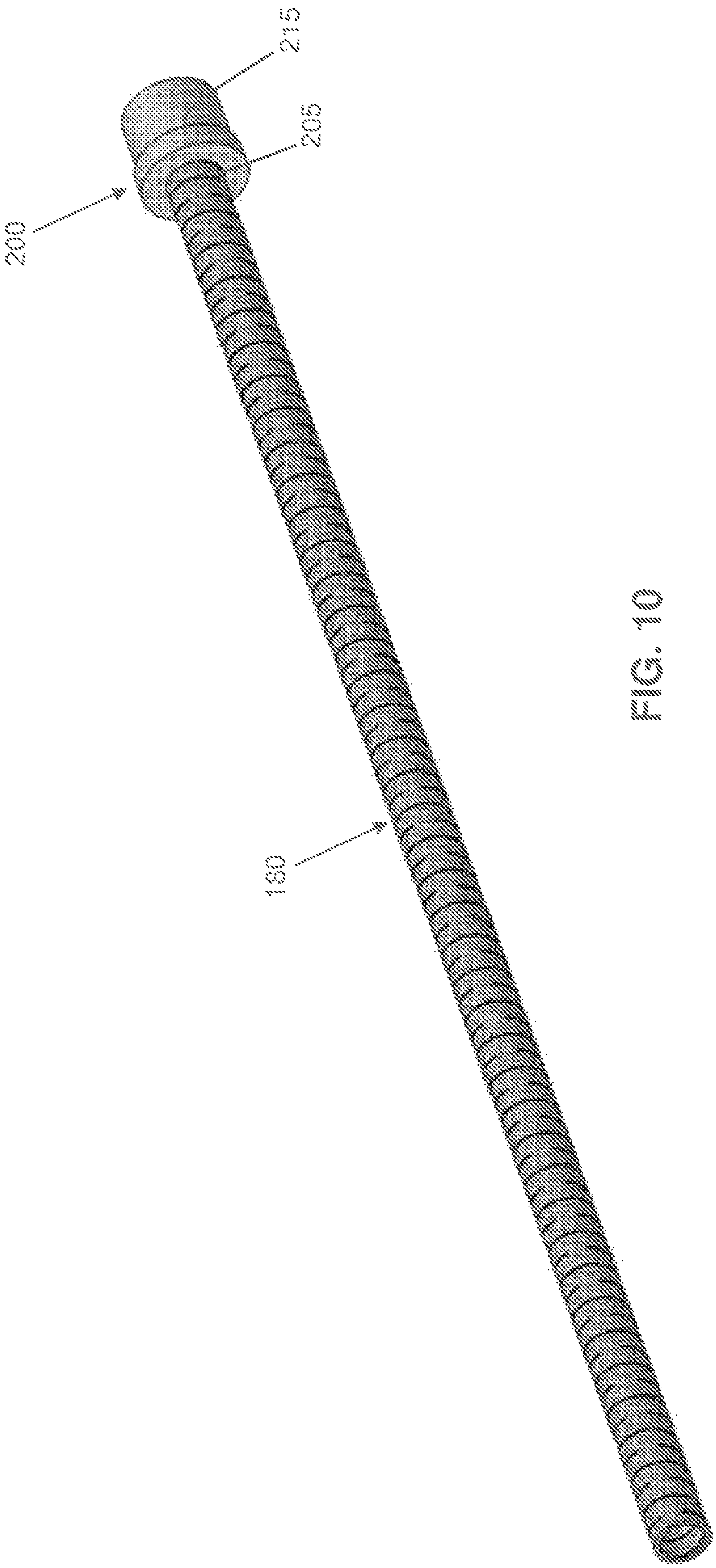
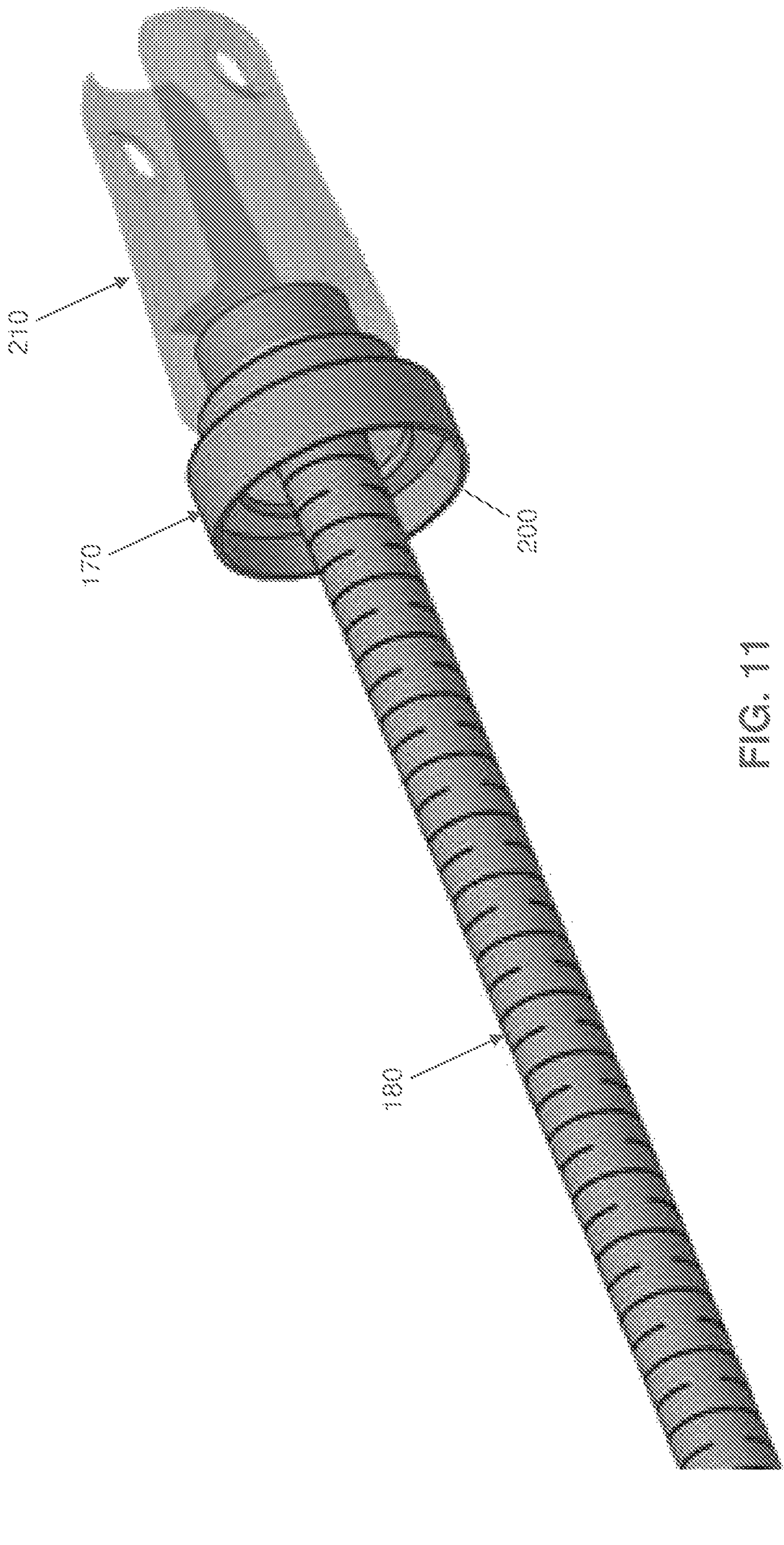


FIG. 10



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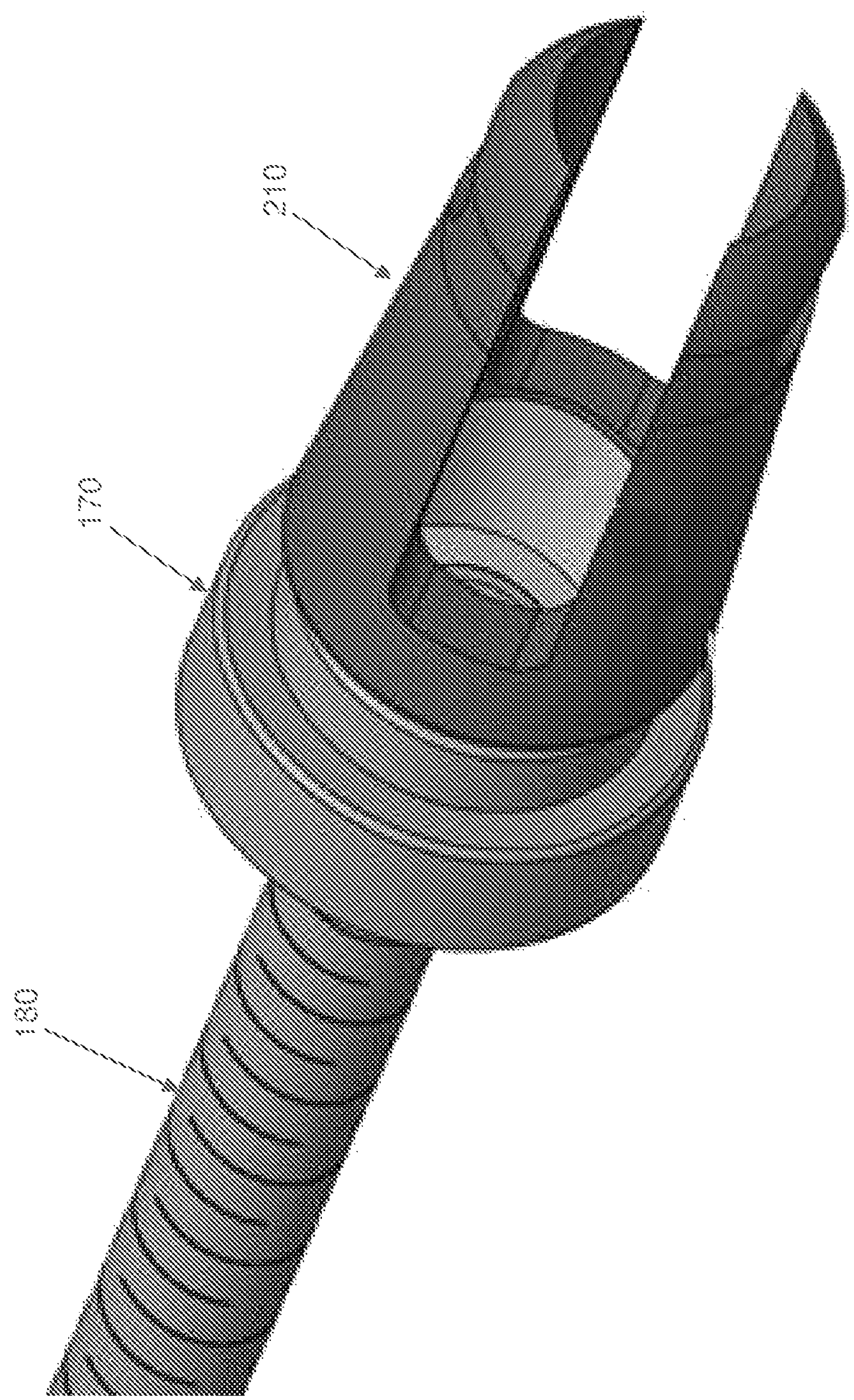

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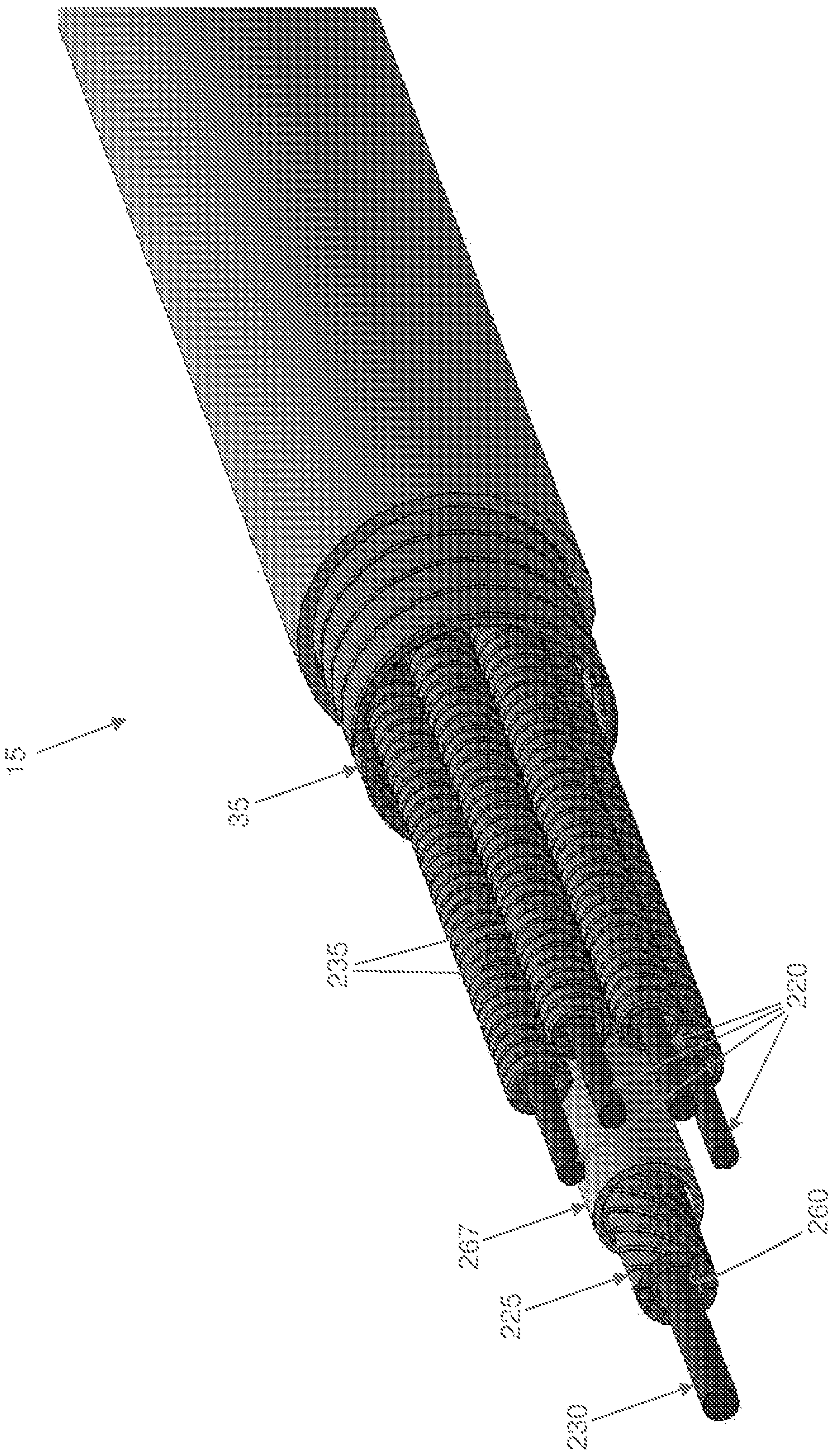

FIG. 13

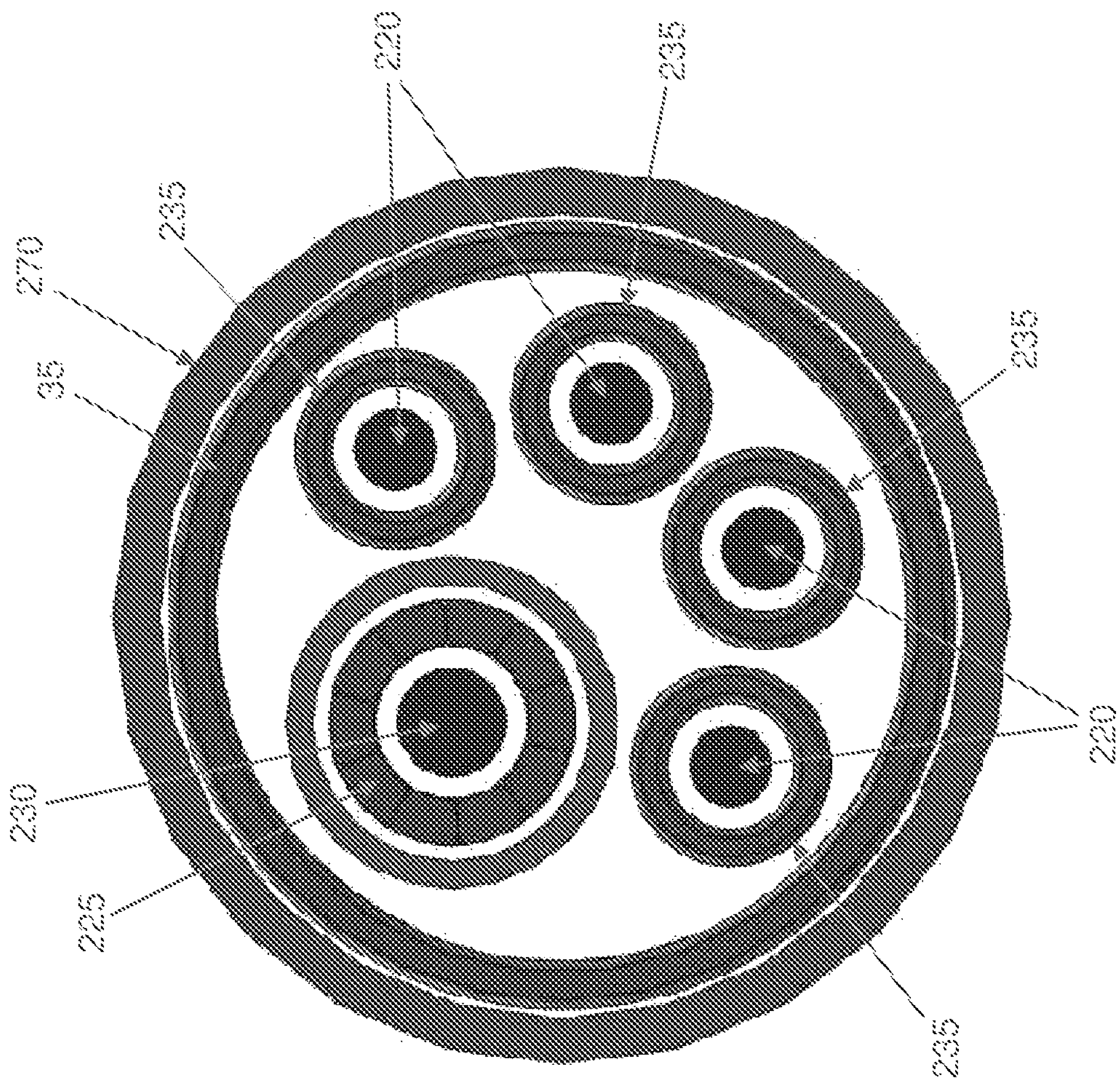

FIG. 14

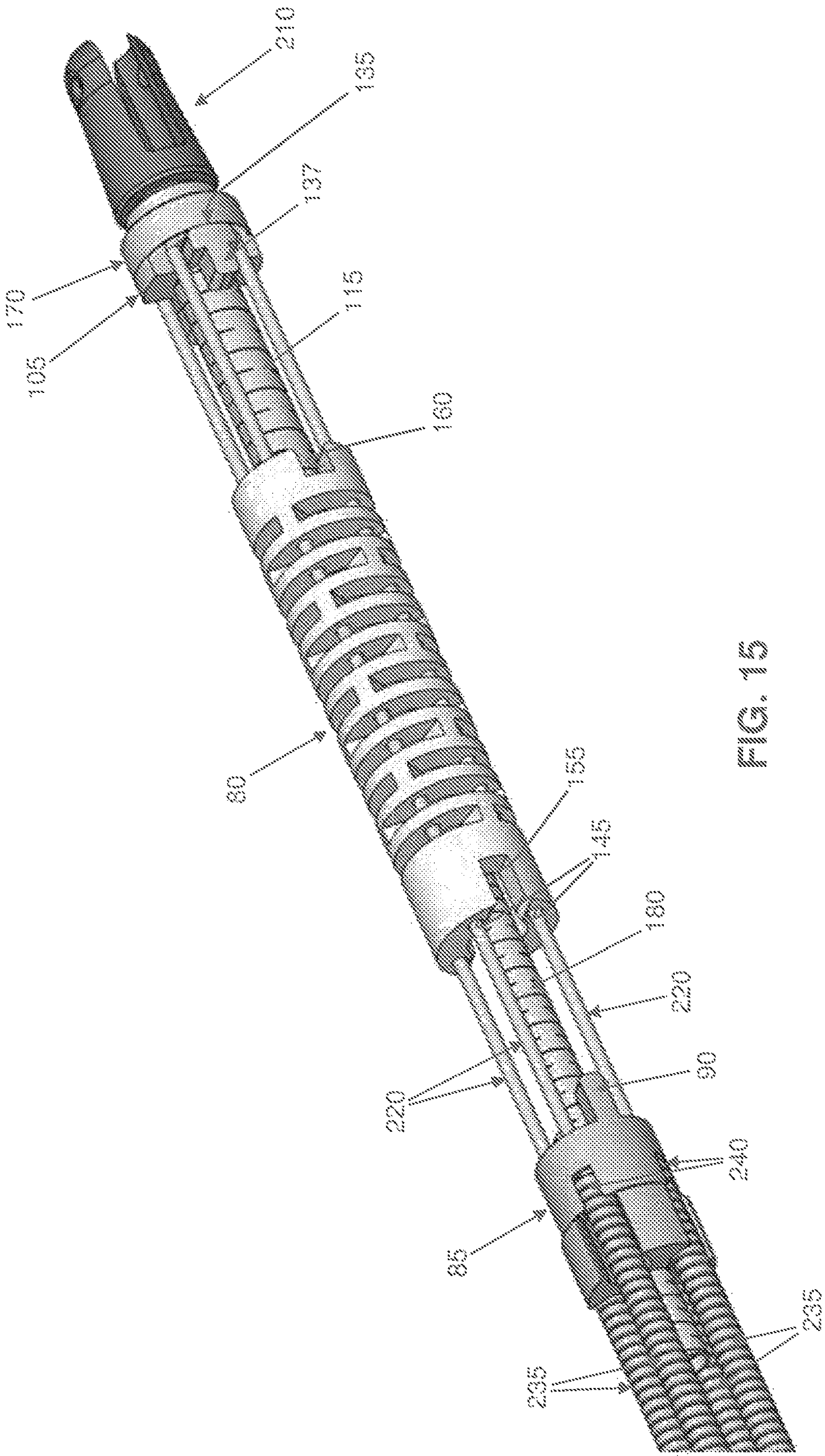
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FIG. 15

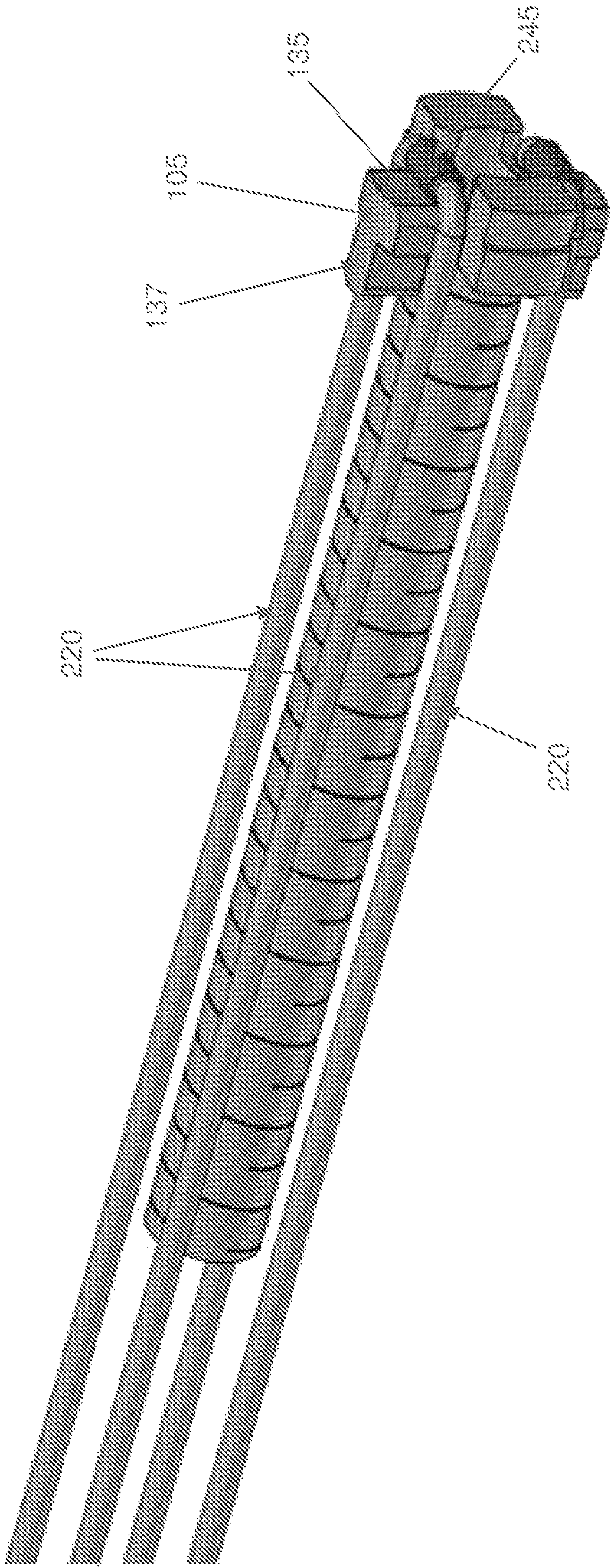

FIG. 16

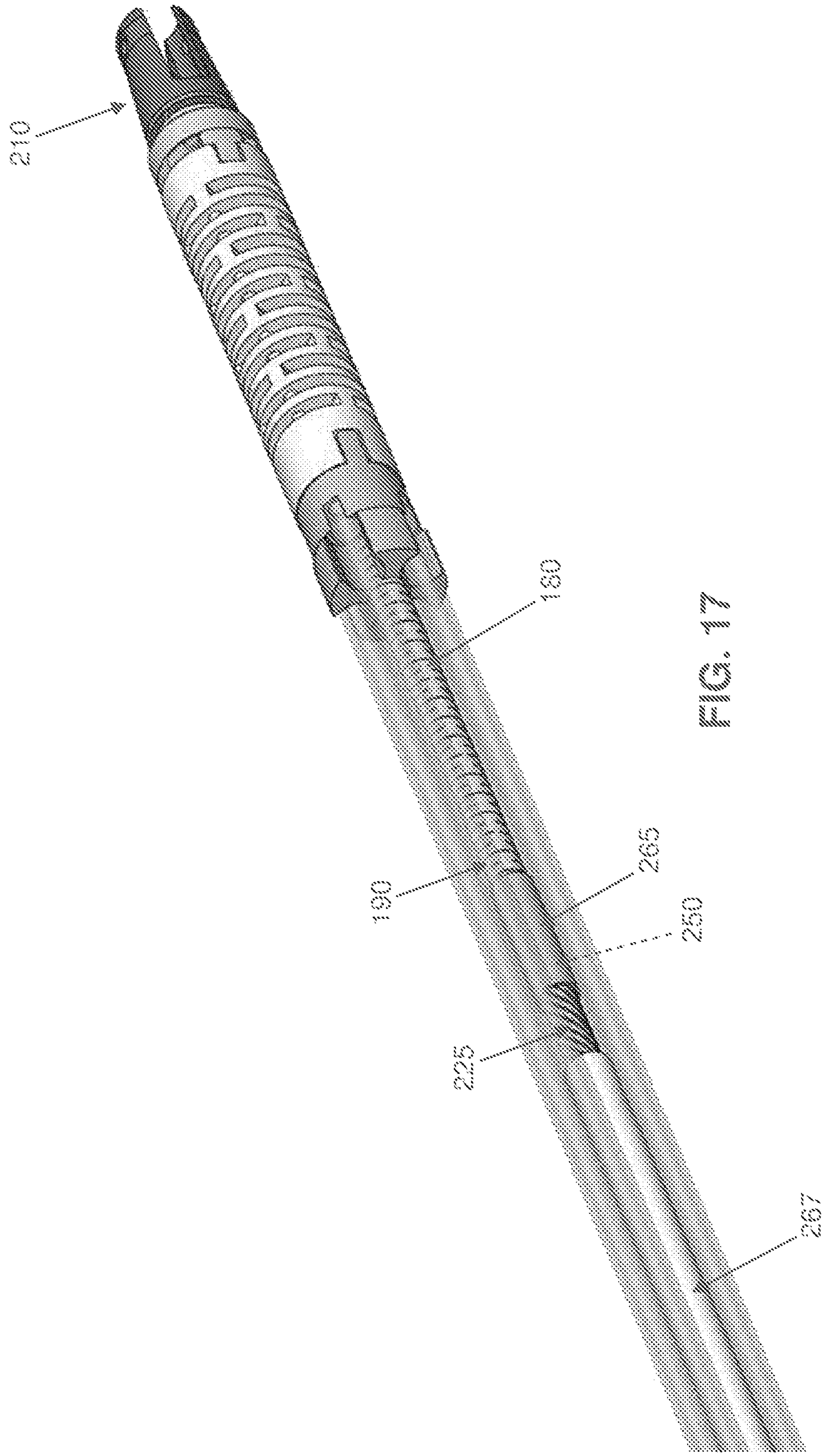

FIG. 17

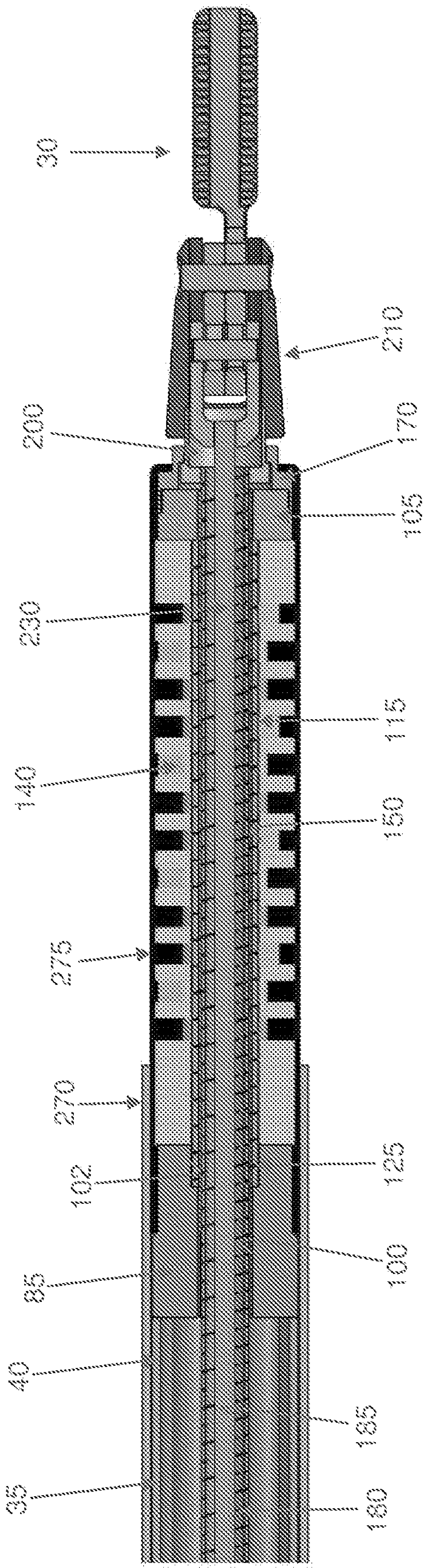
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FIG. 18

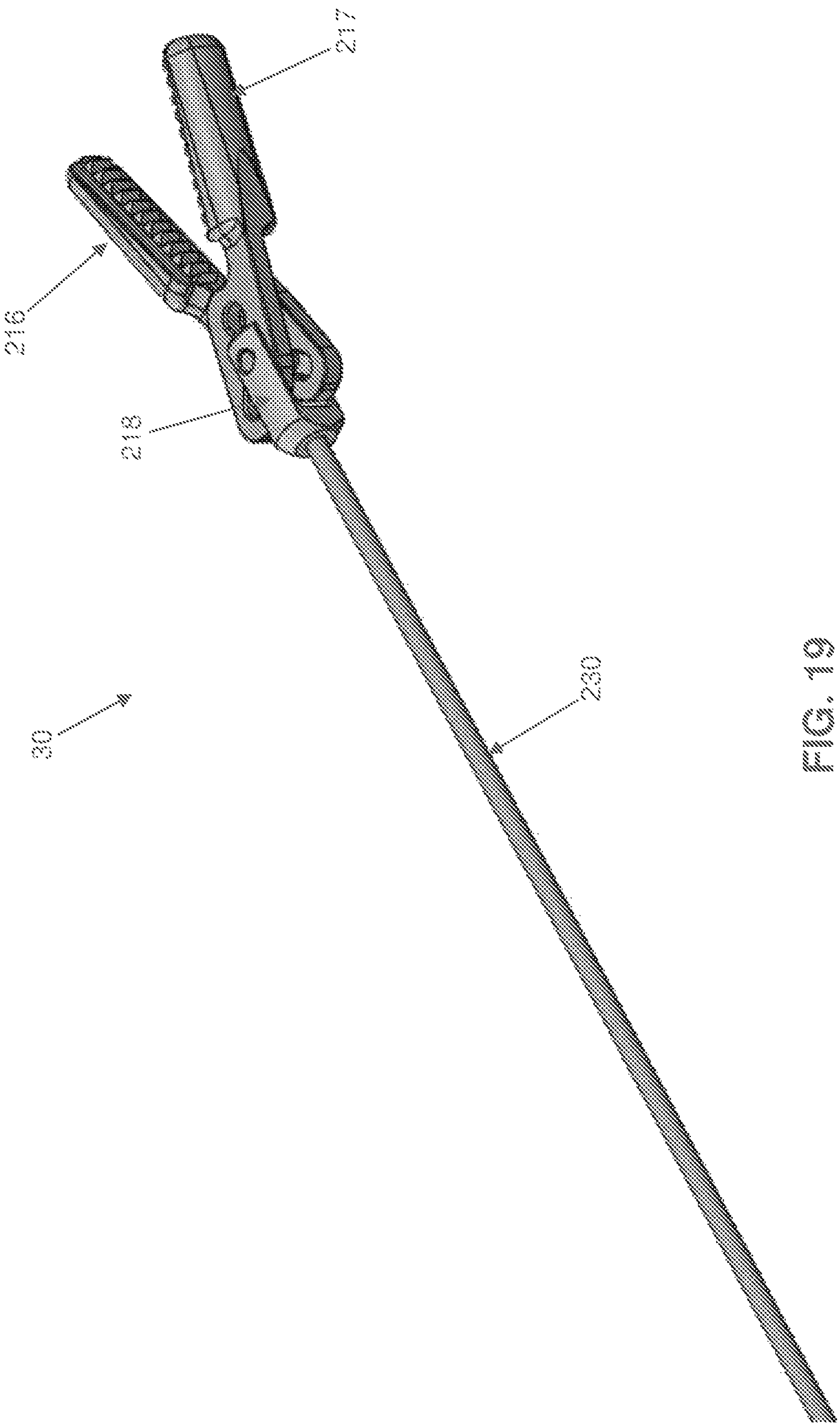
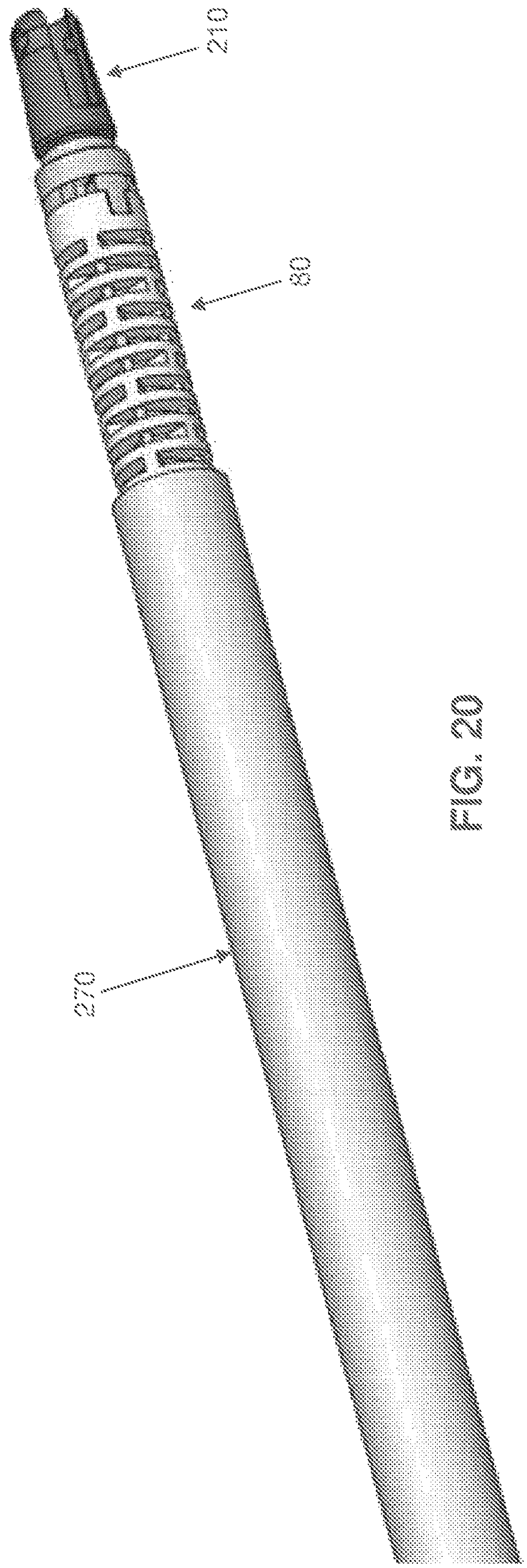


FIG. 19



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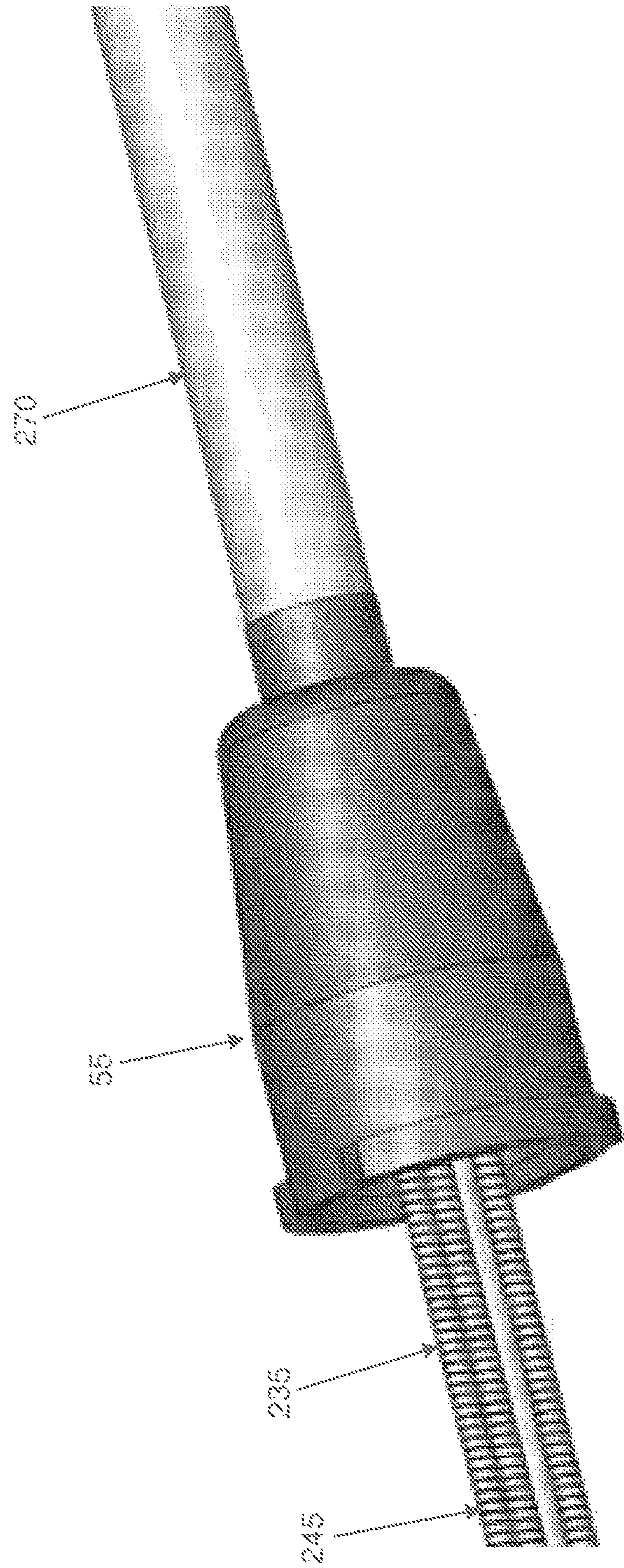

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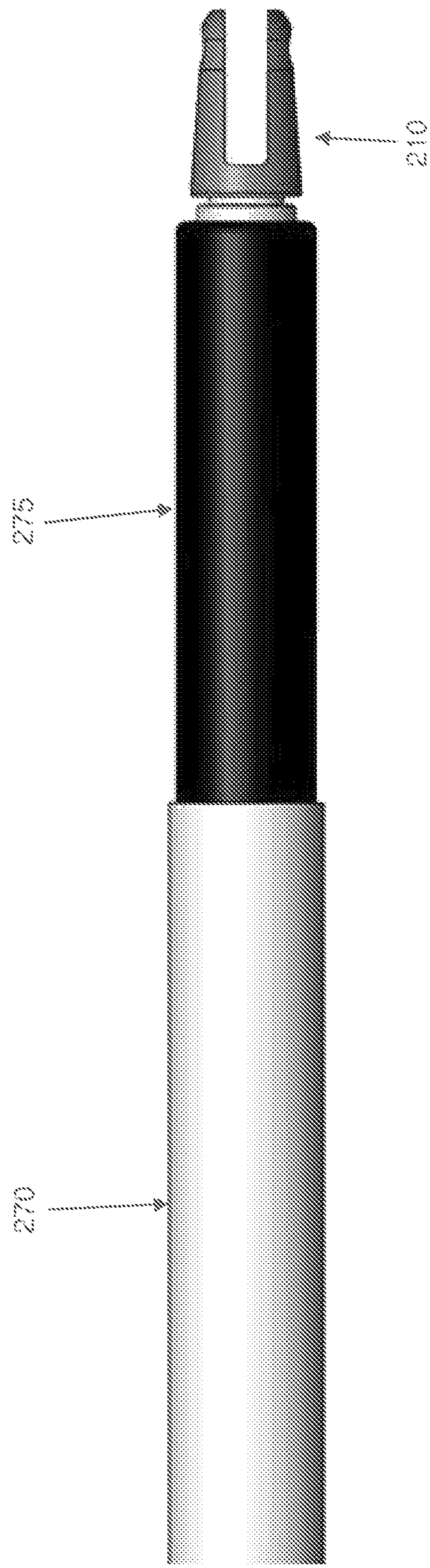

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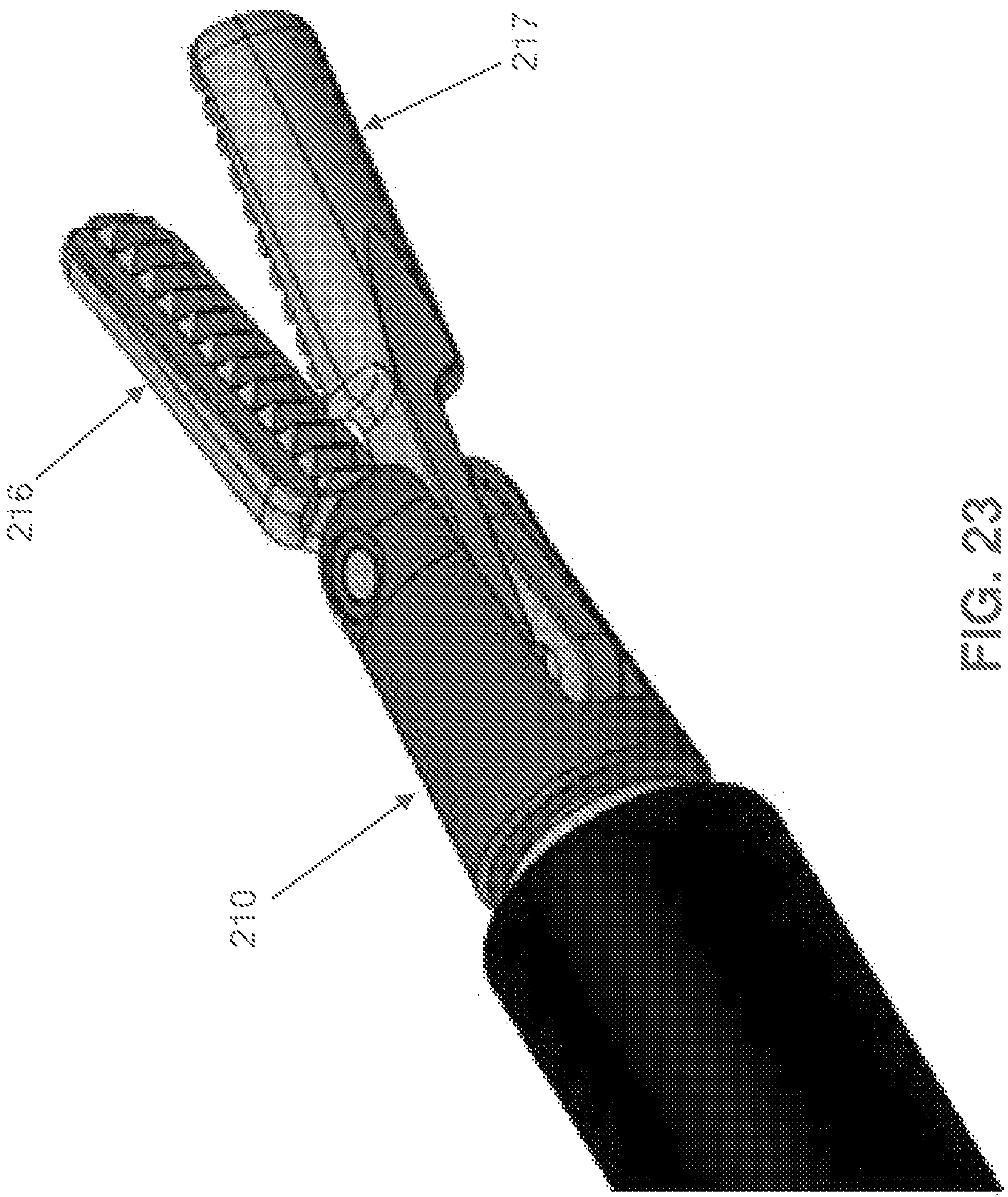

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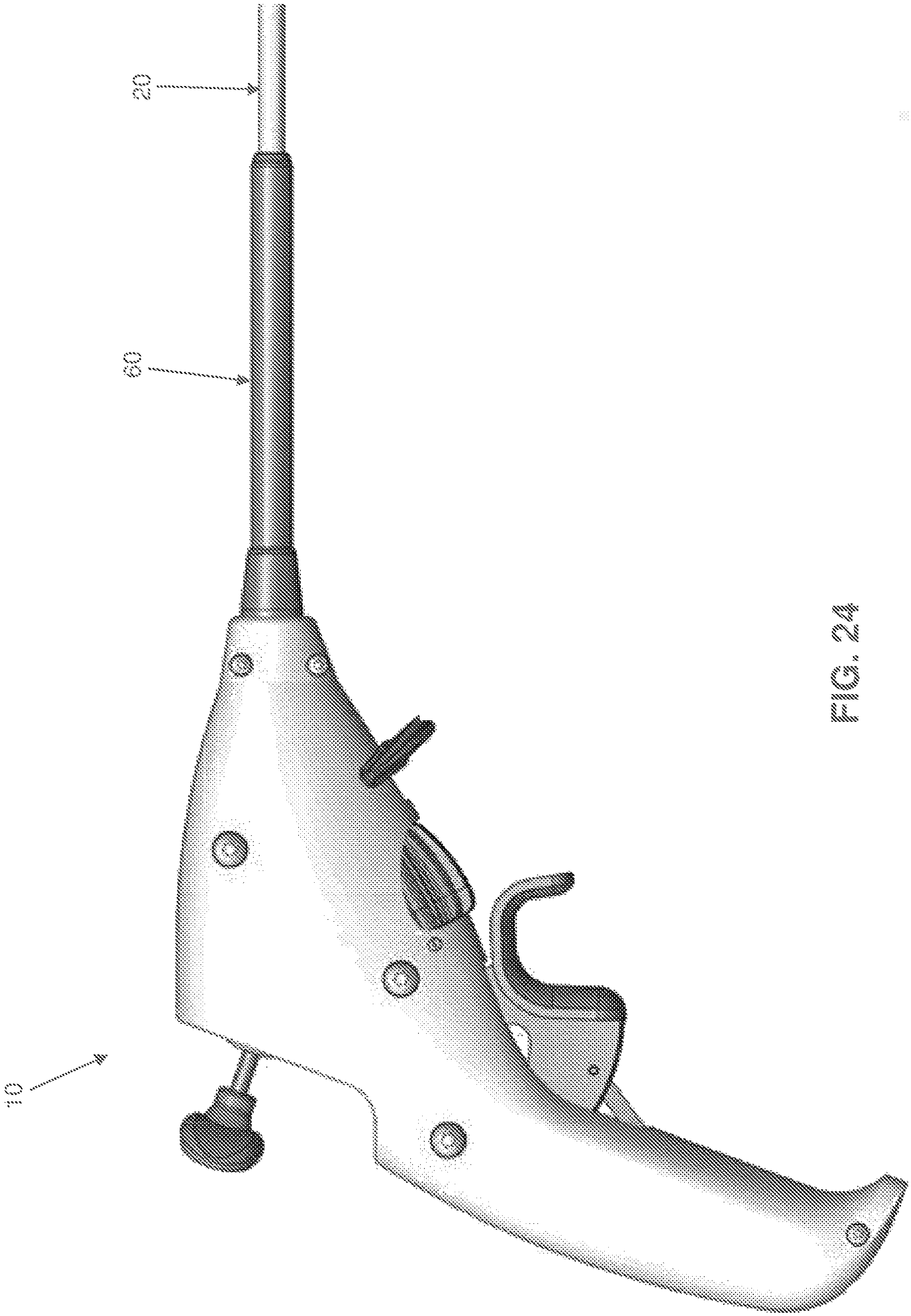

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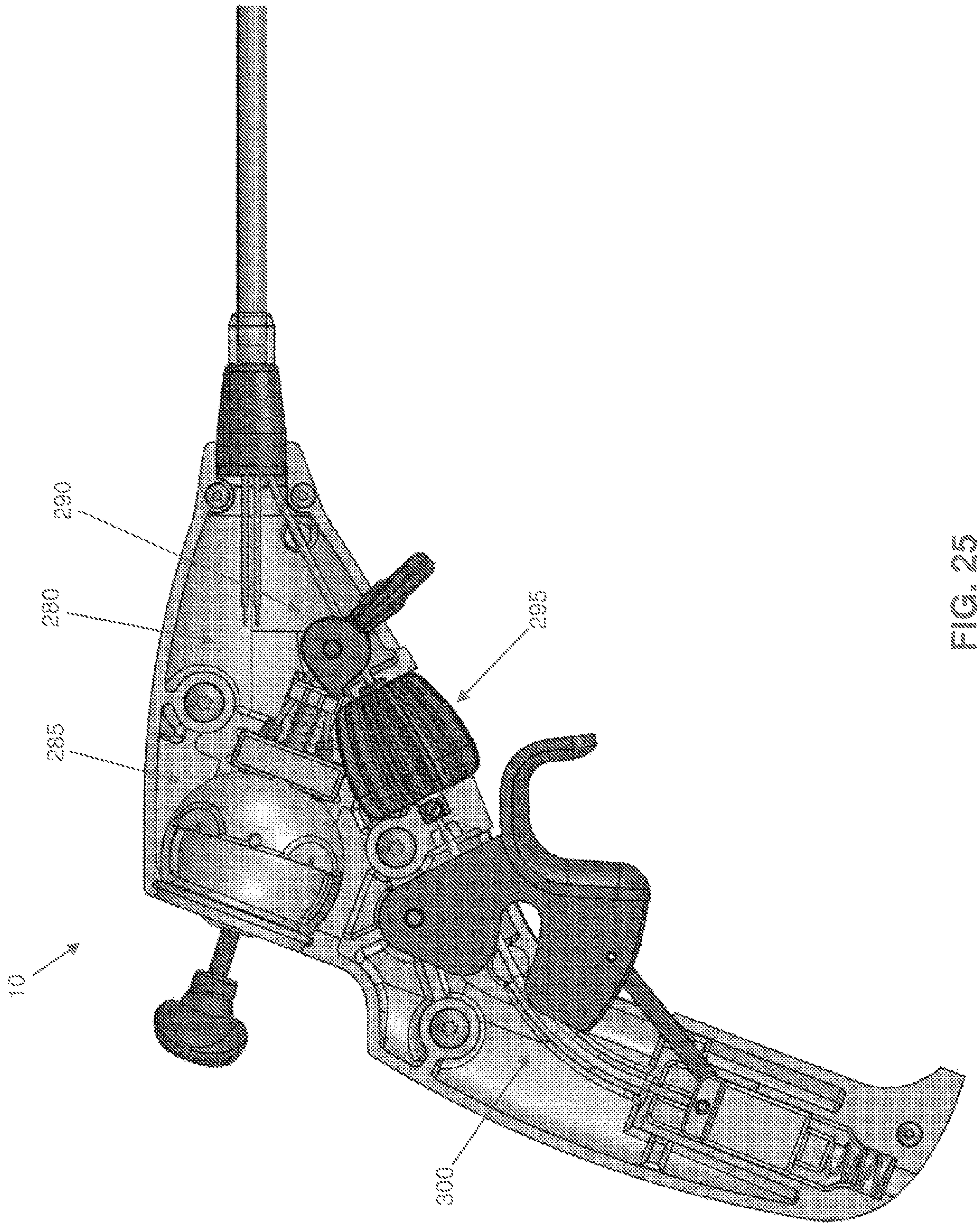

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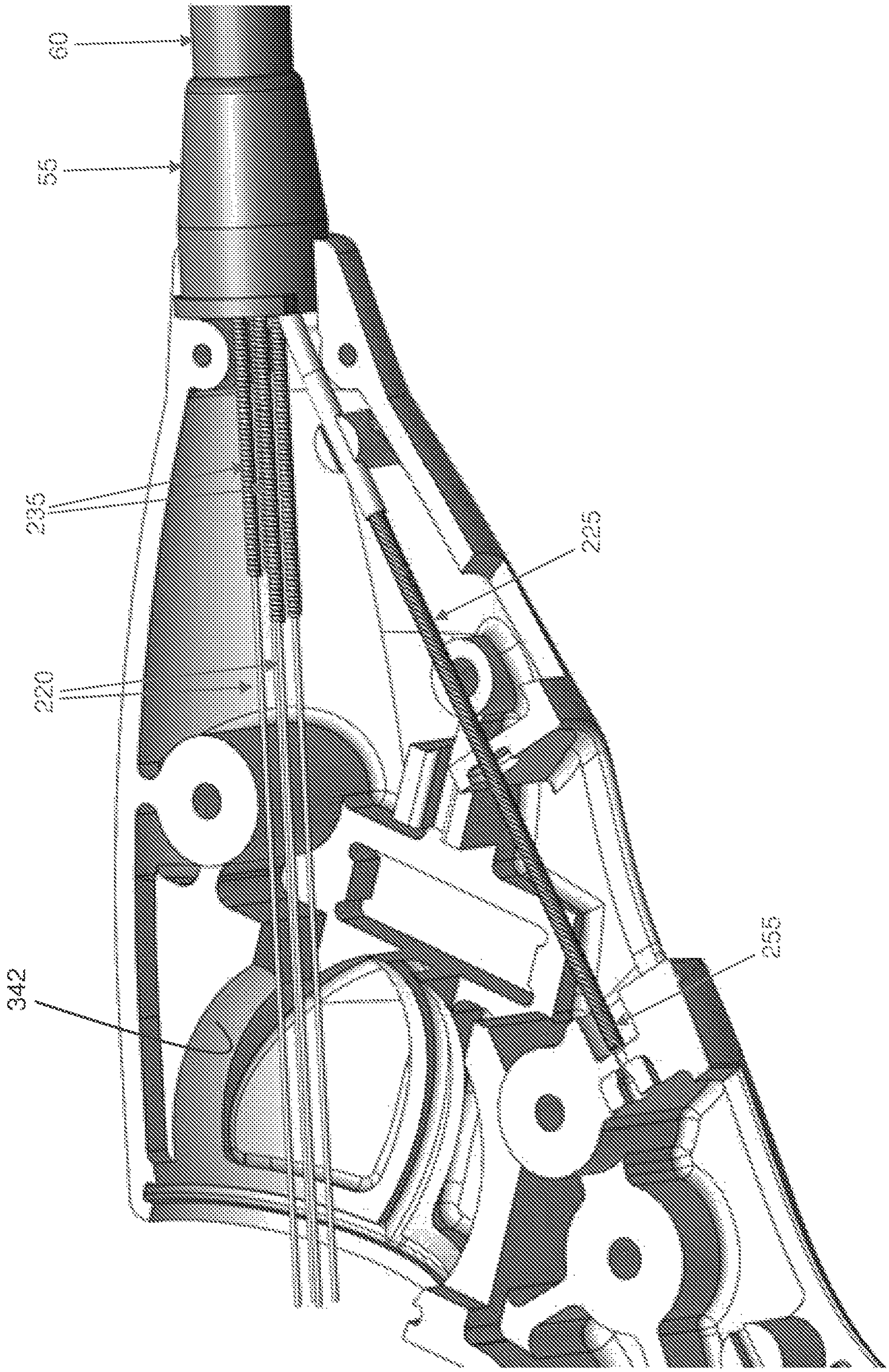

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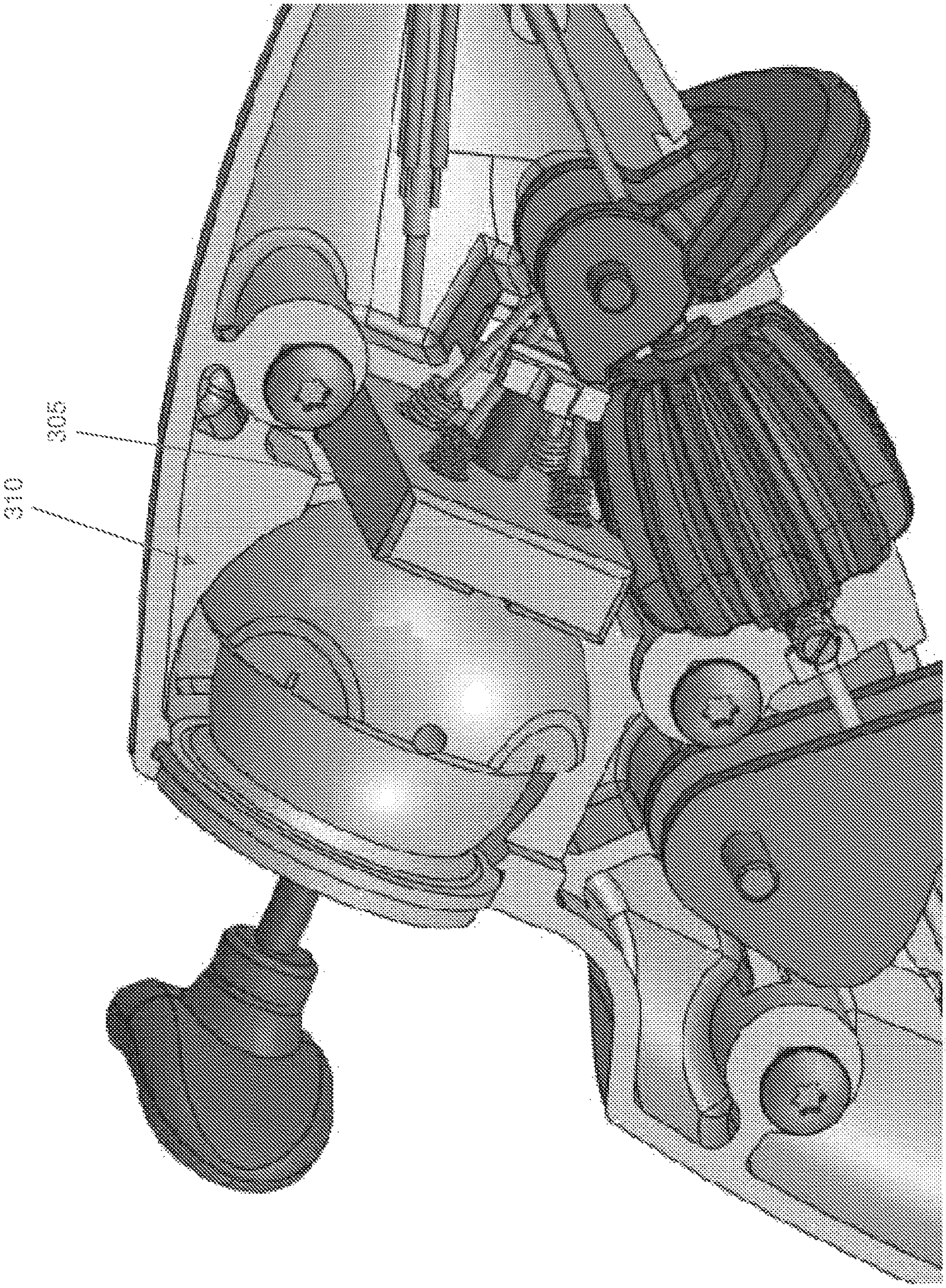
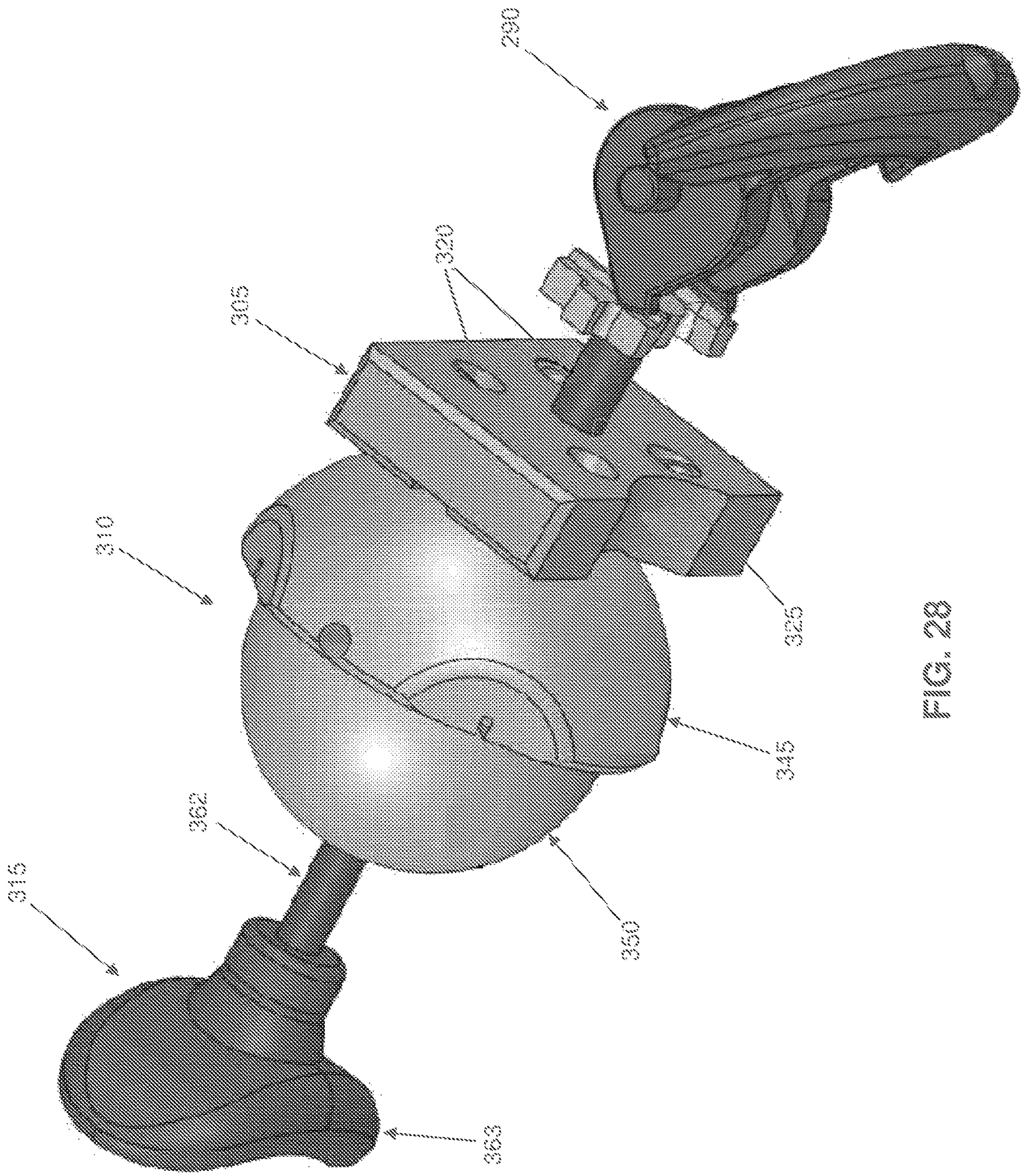


FIG. 27



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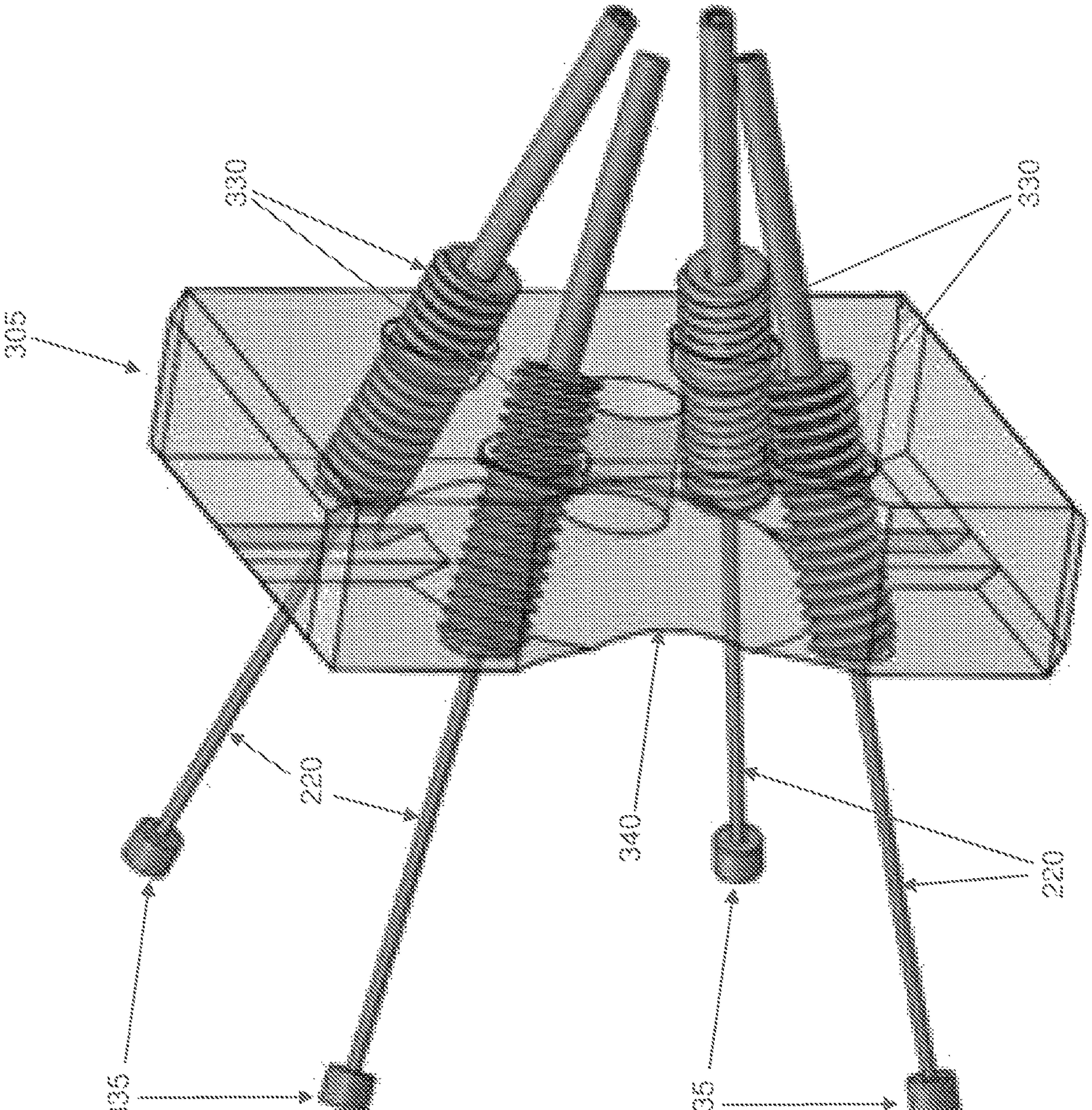

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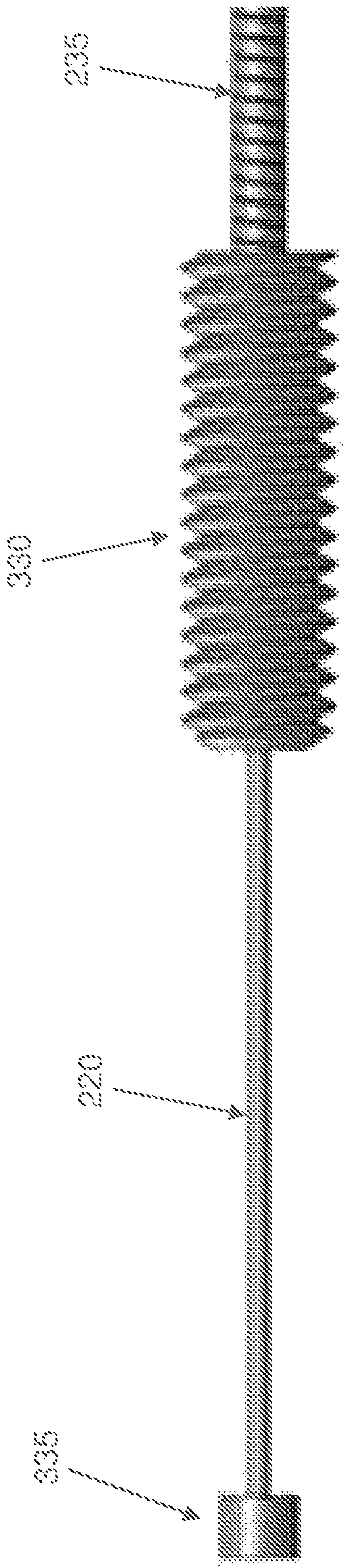


FIG. 30

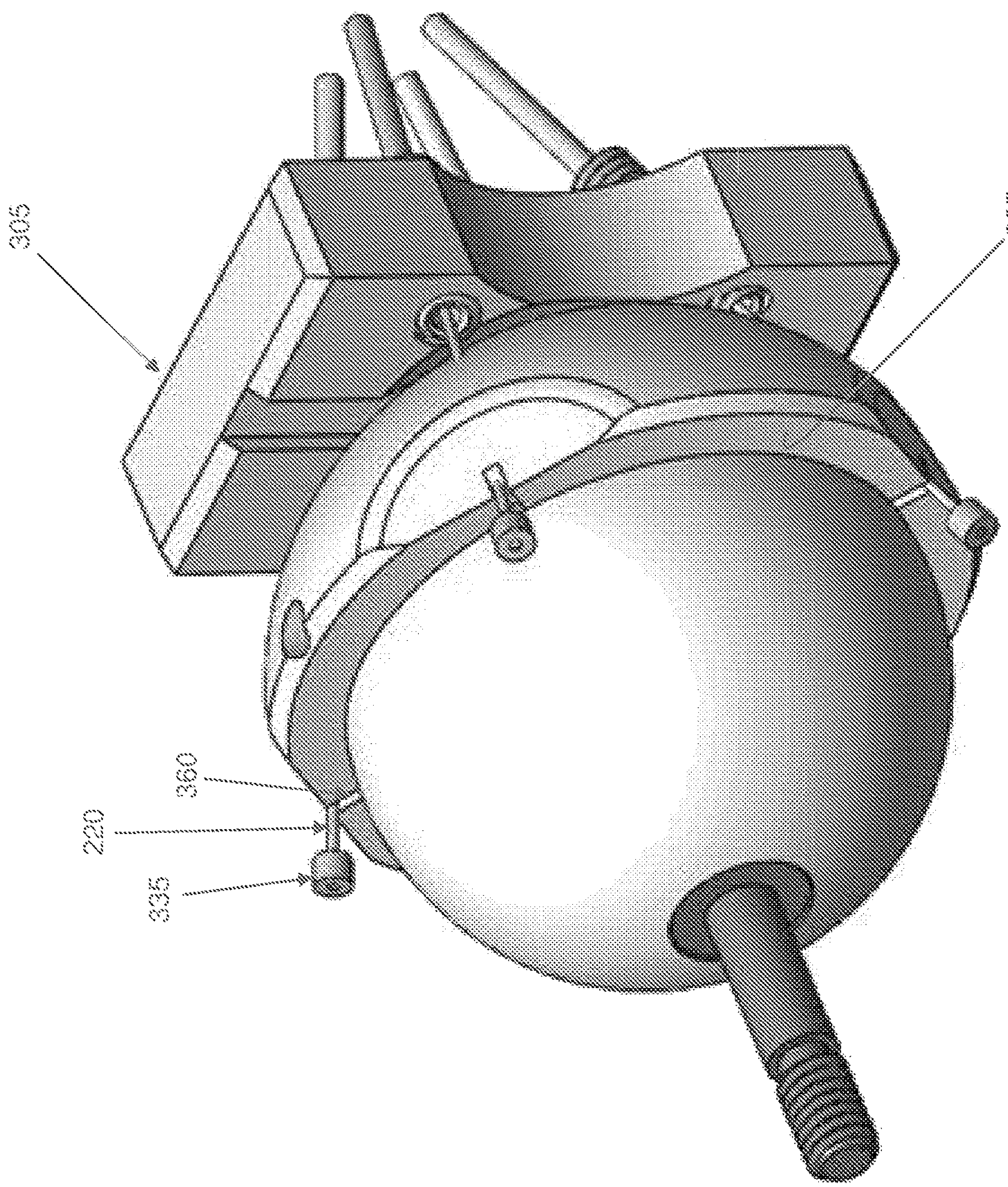
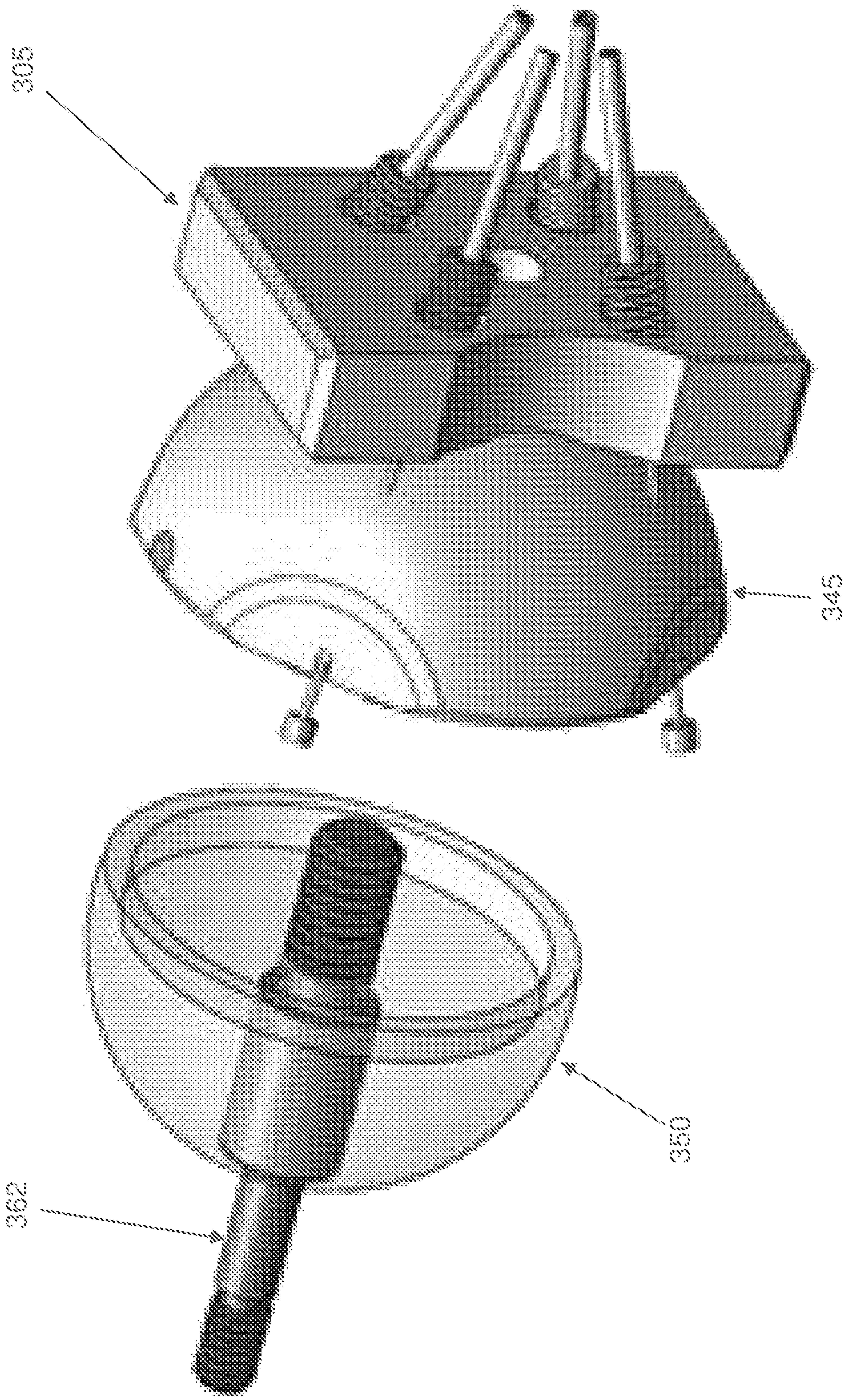


FIG. 31



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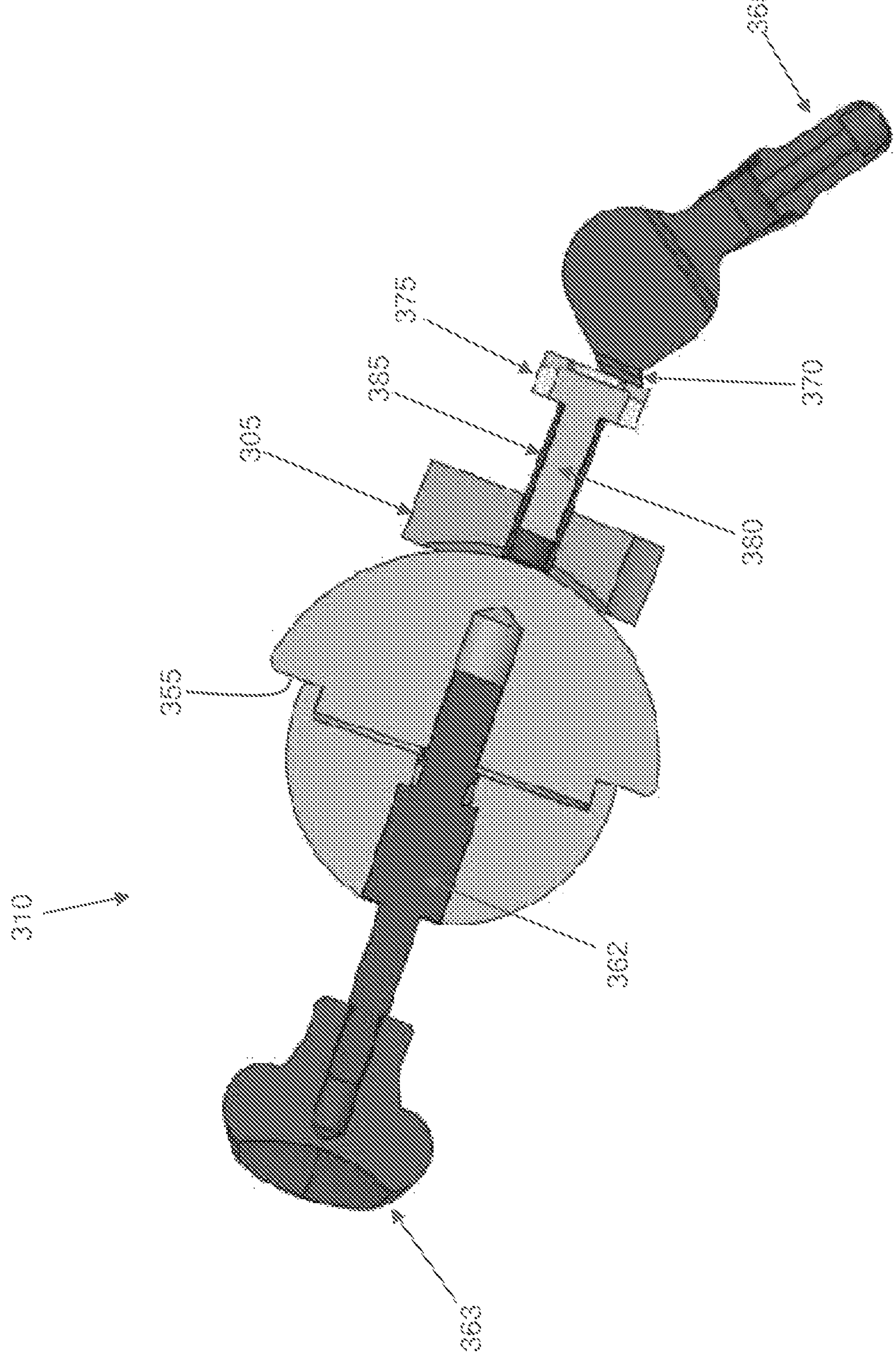


FIG. 33

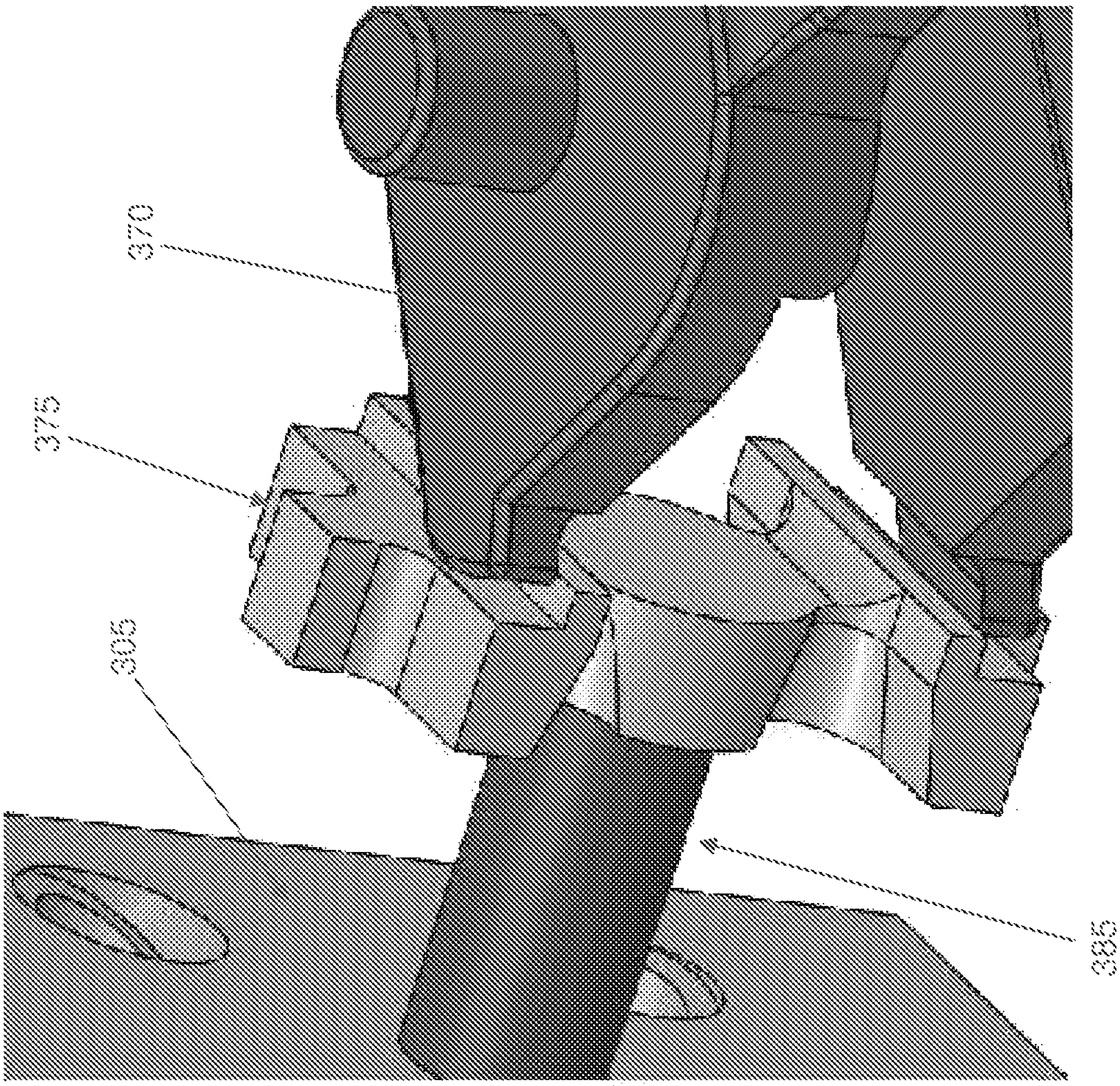


FIG. 34

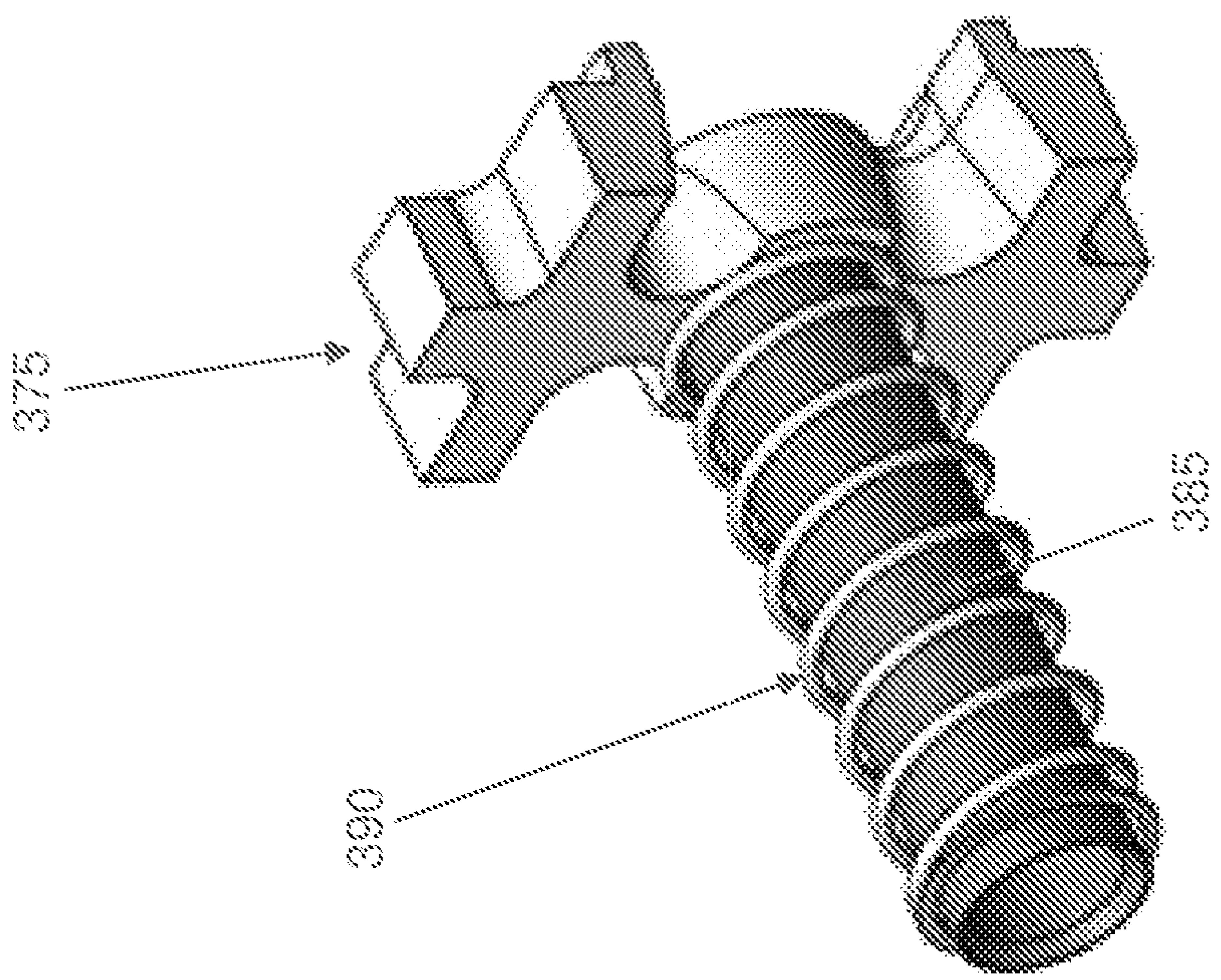


FIG. 35

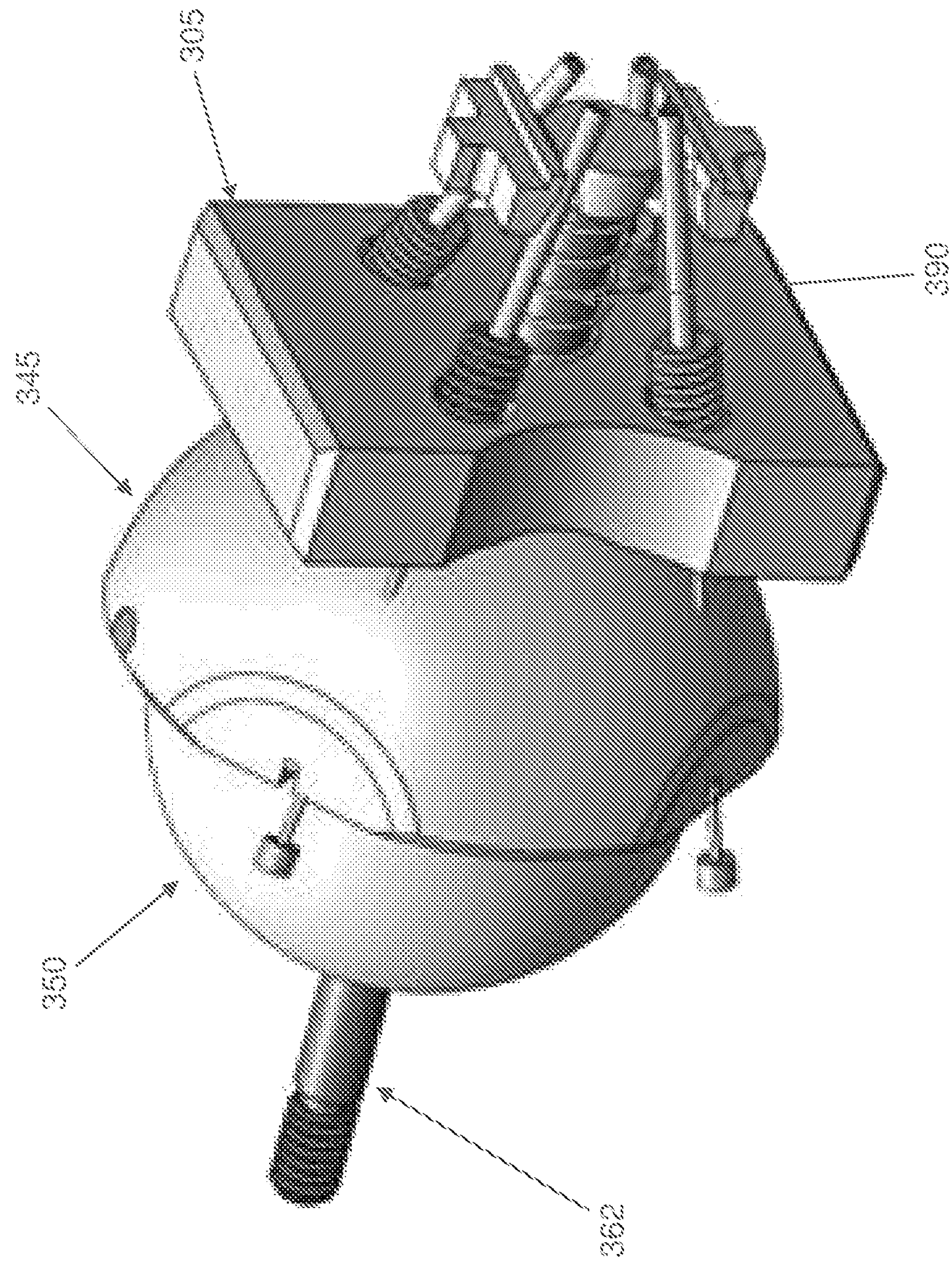


FIG. 36

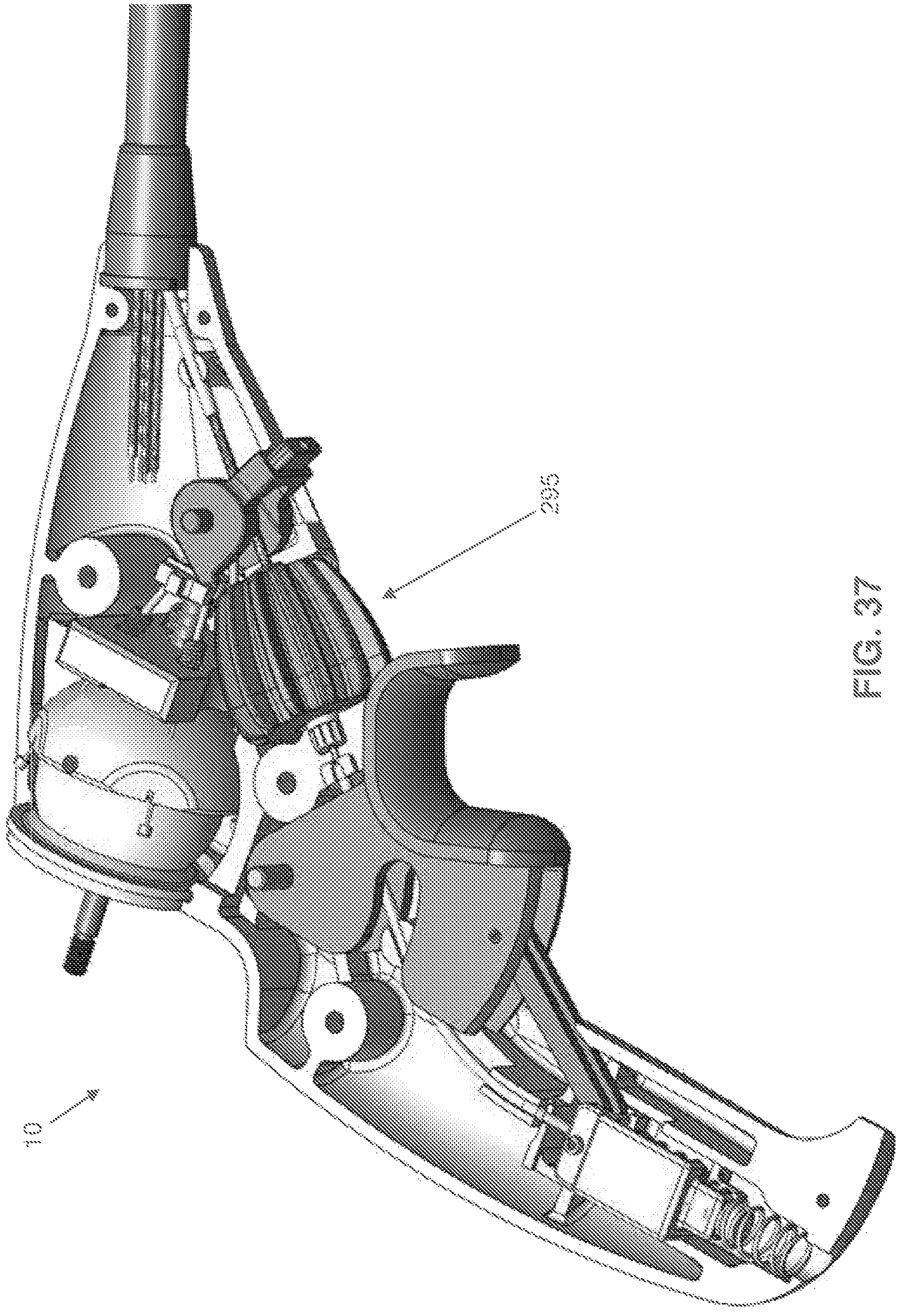


FIG. 37

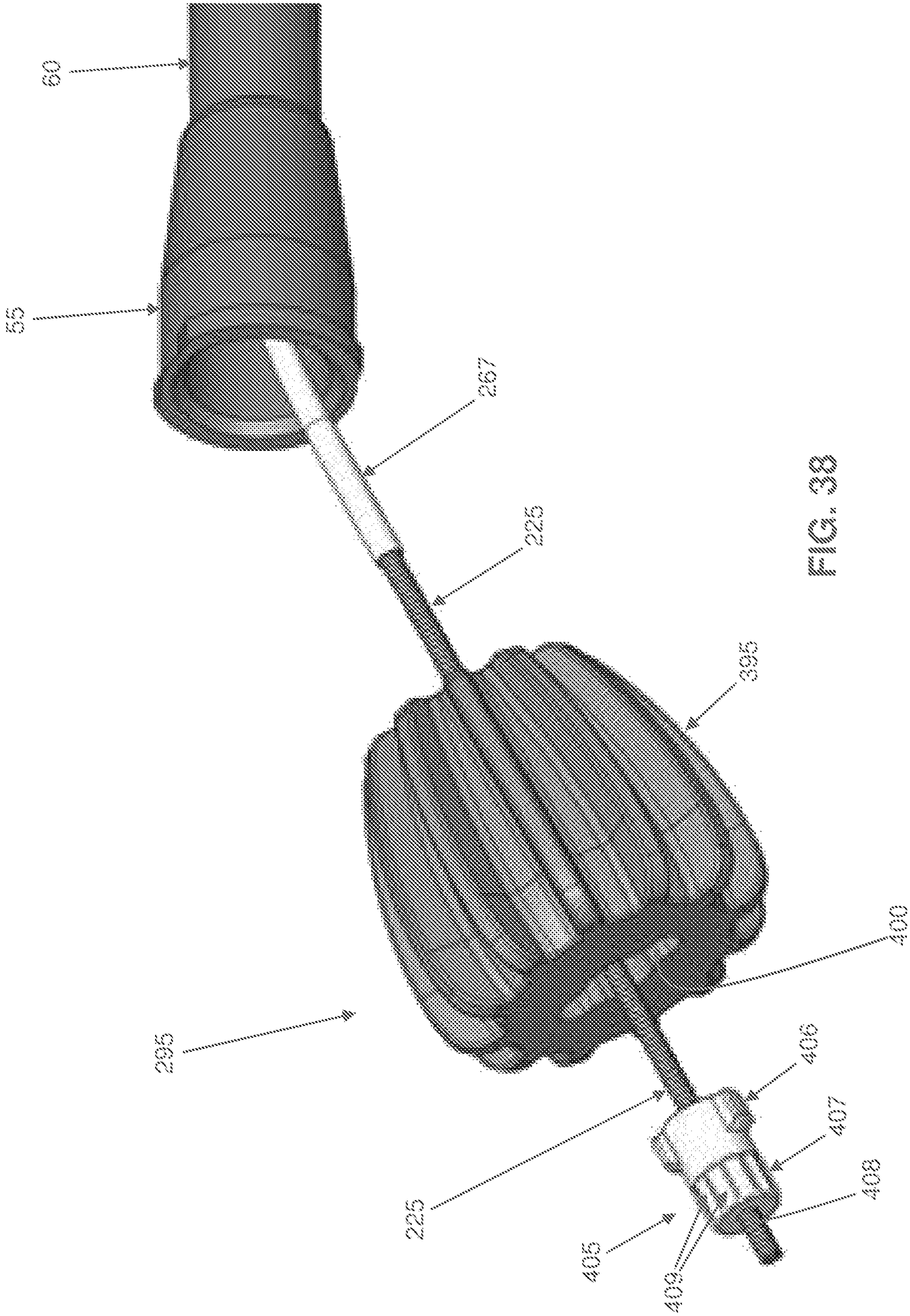


FIG. 38

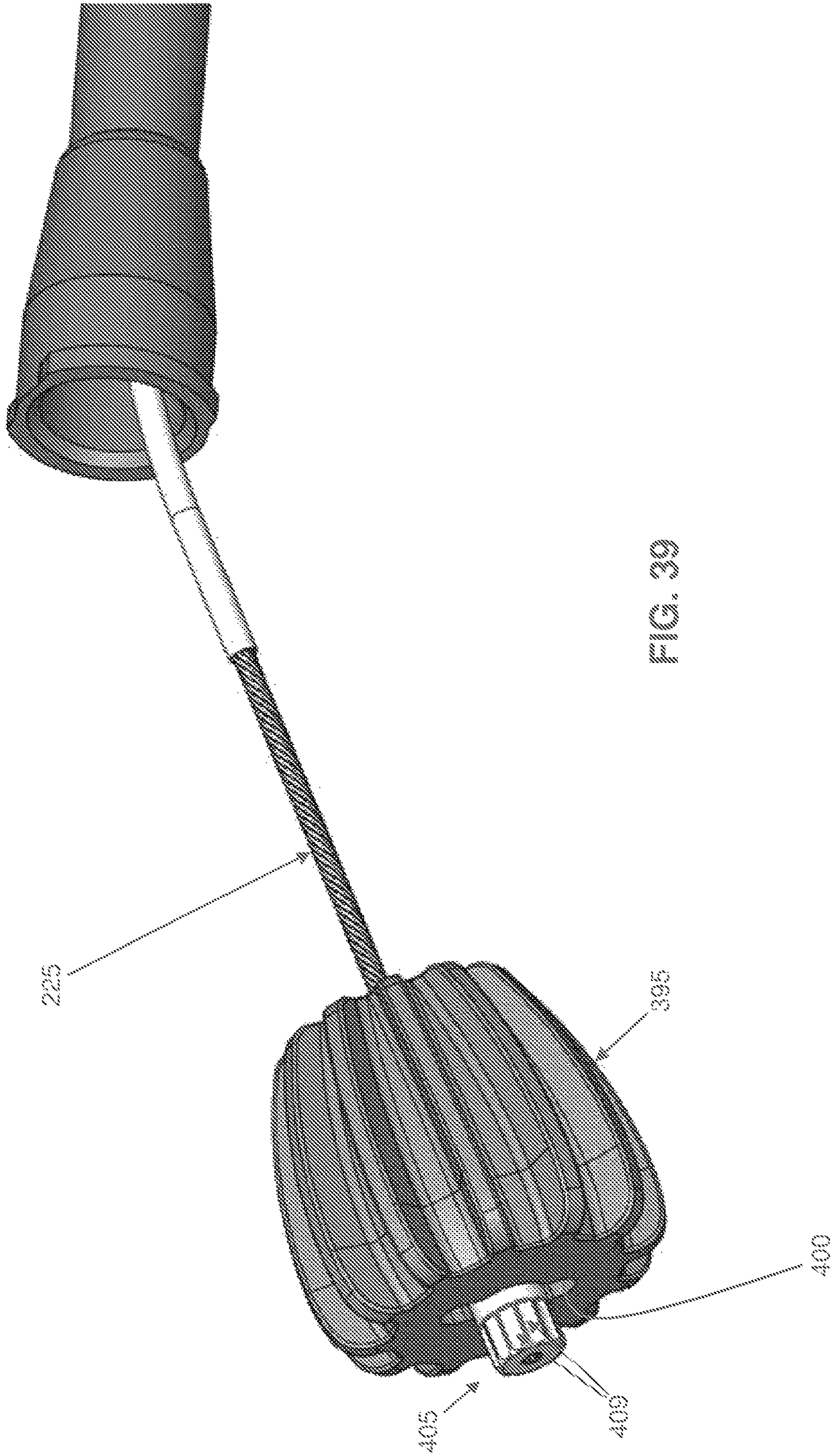


FIG. 39

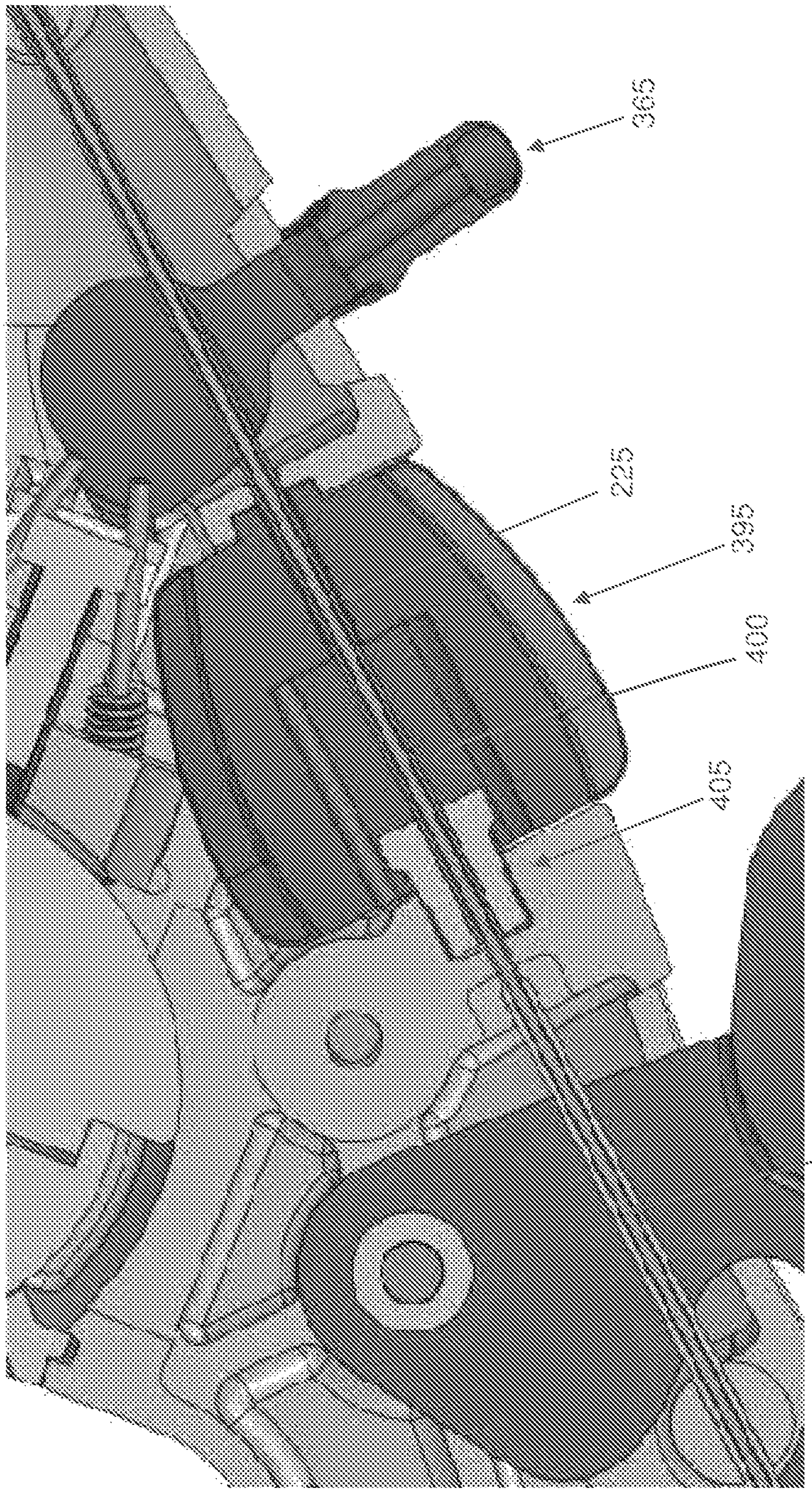


FIG. 40

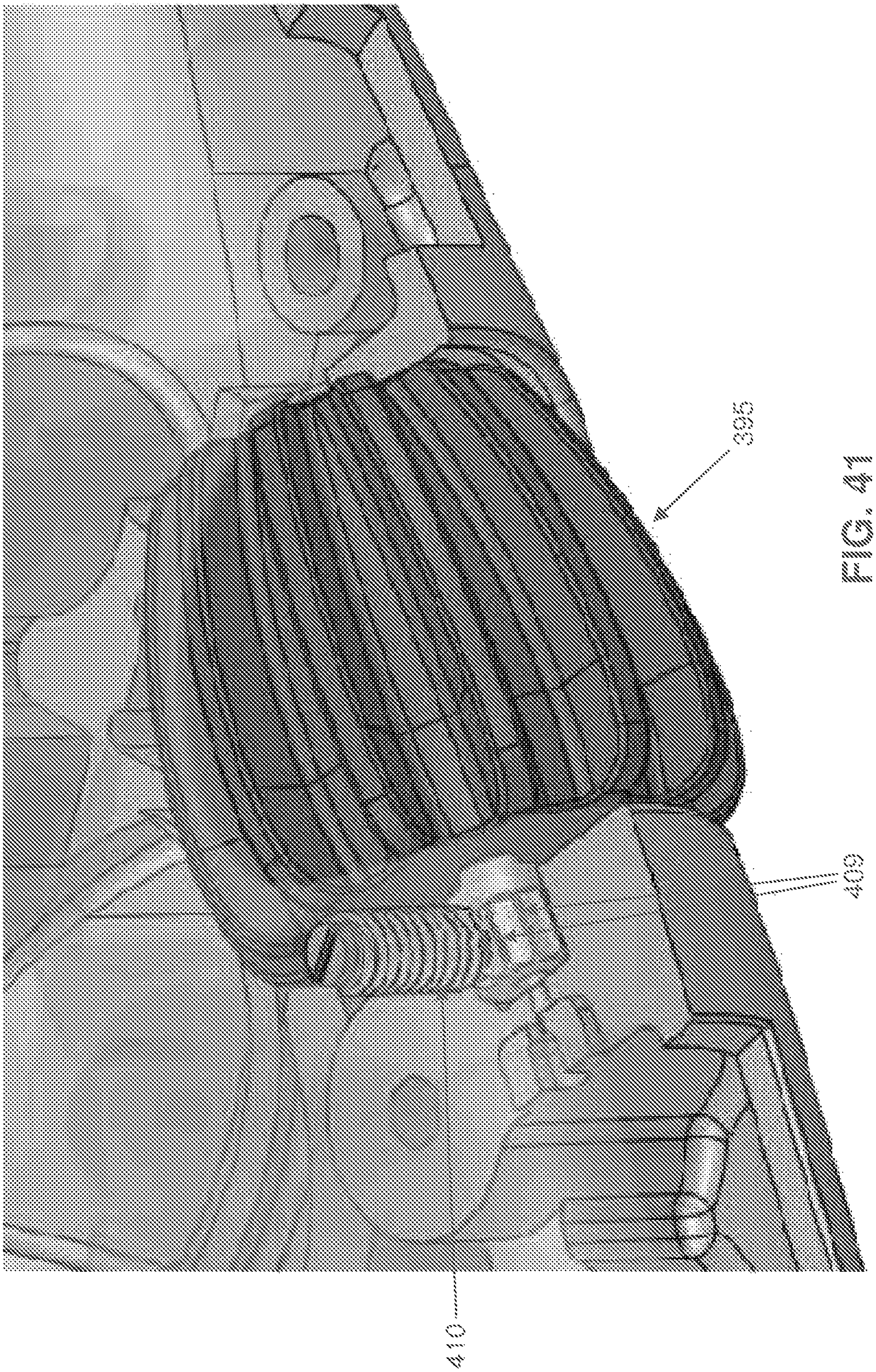


FIG. 41

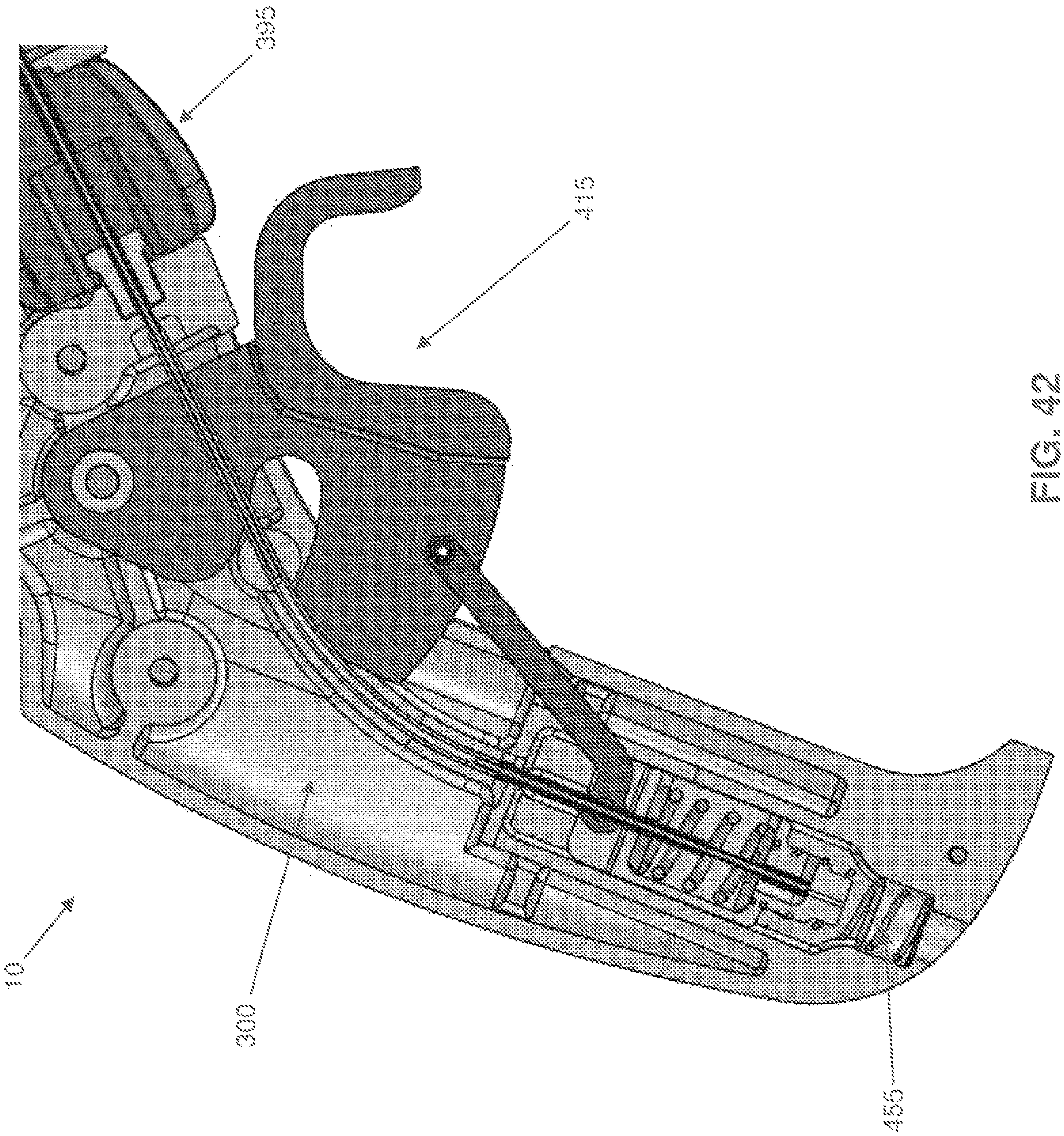


FIG. 42

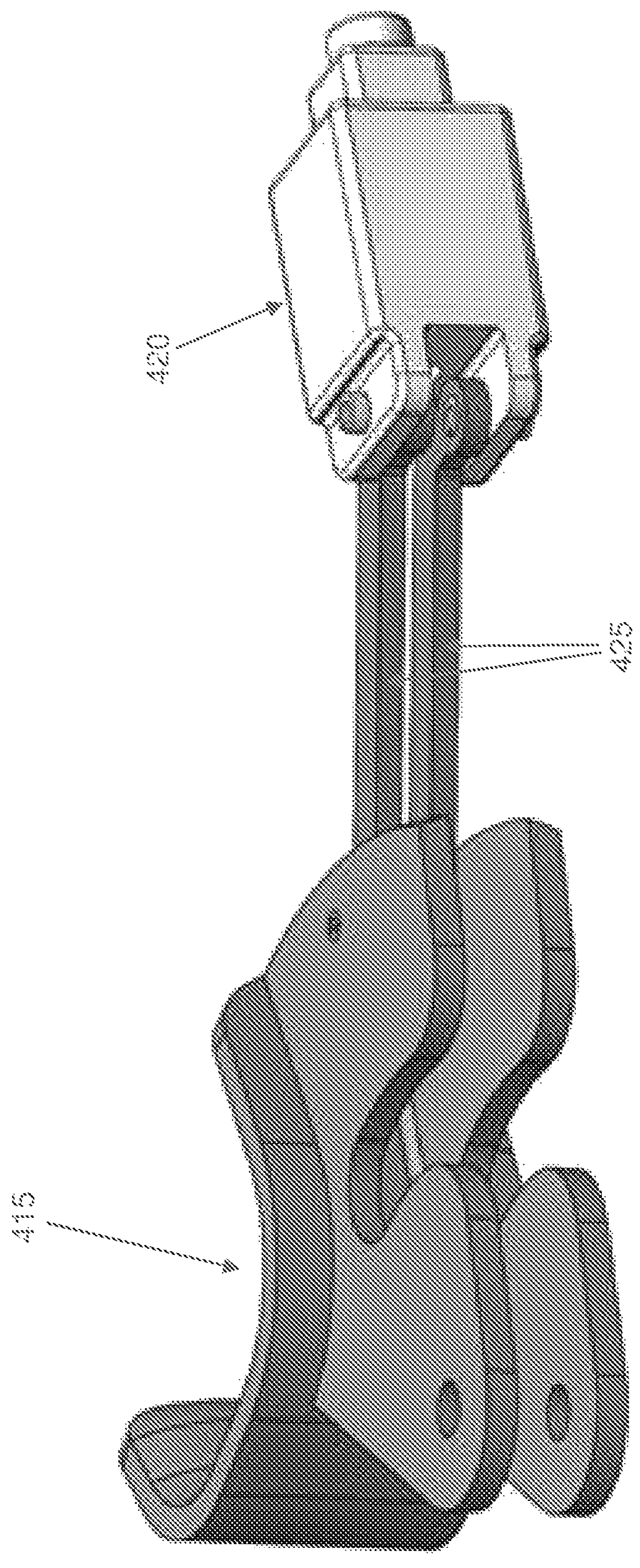


FIG. 43

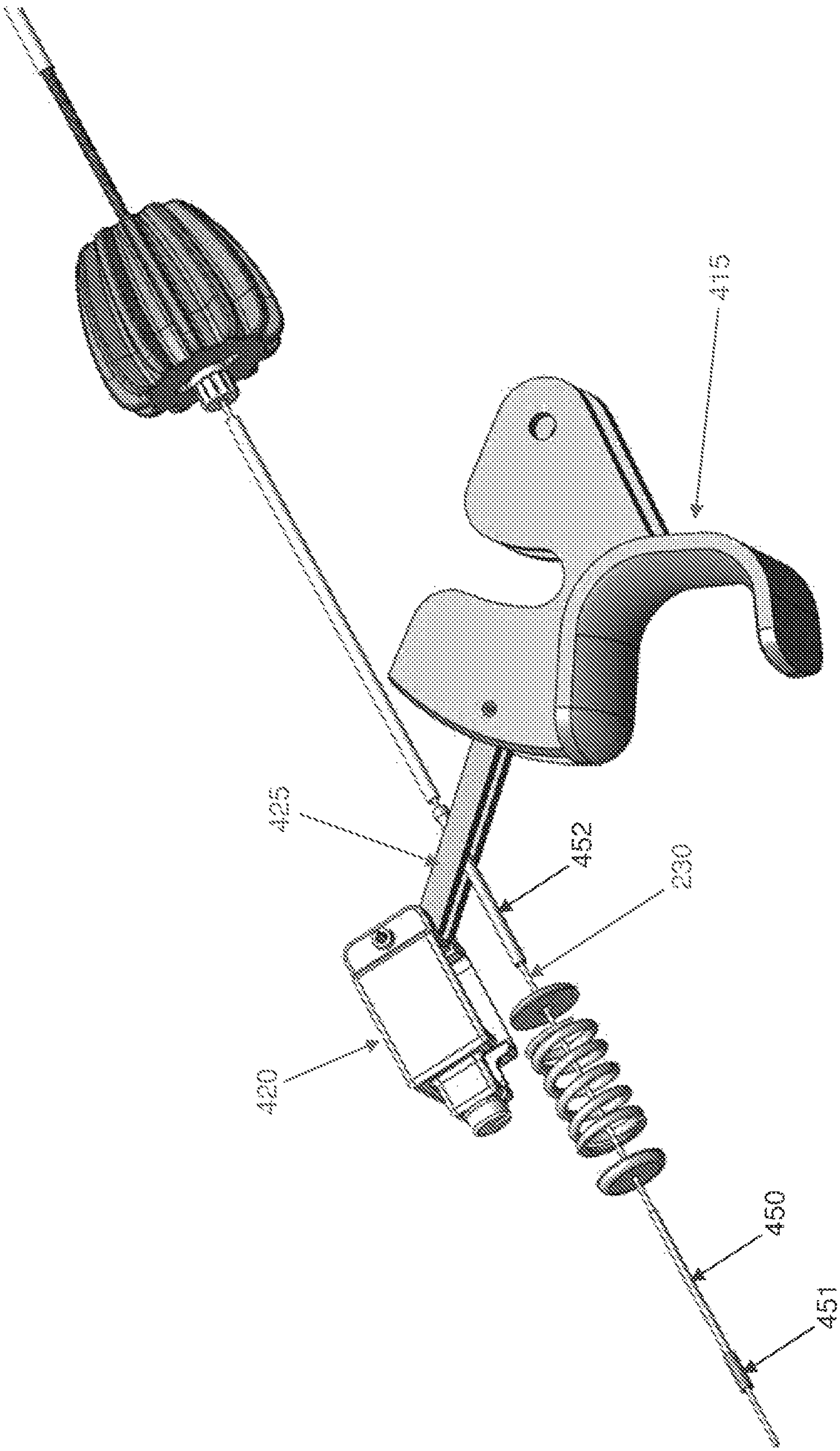


FIG. 44

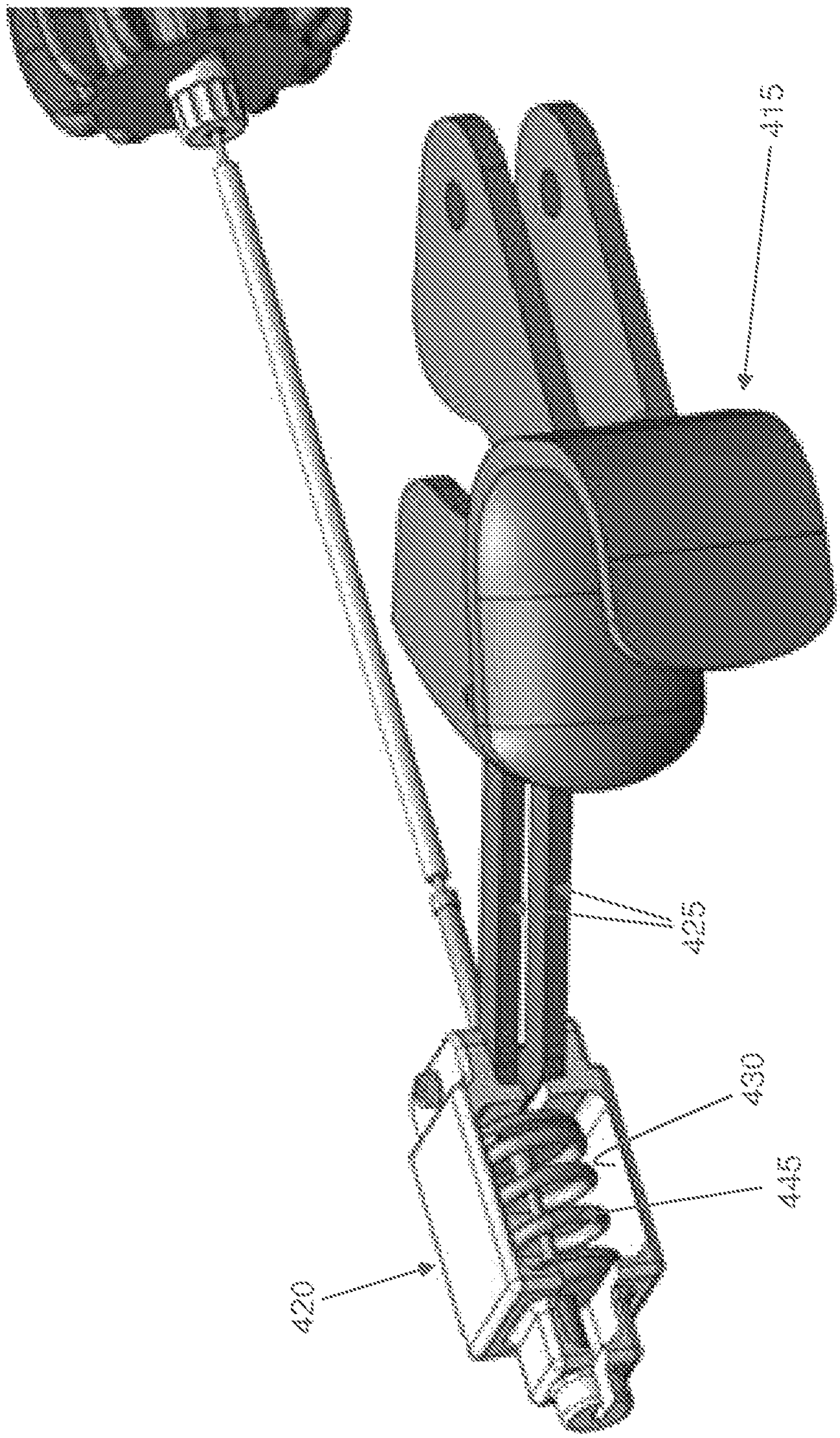


FIG. 45

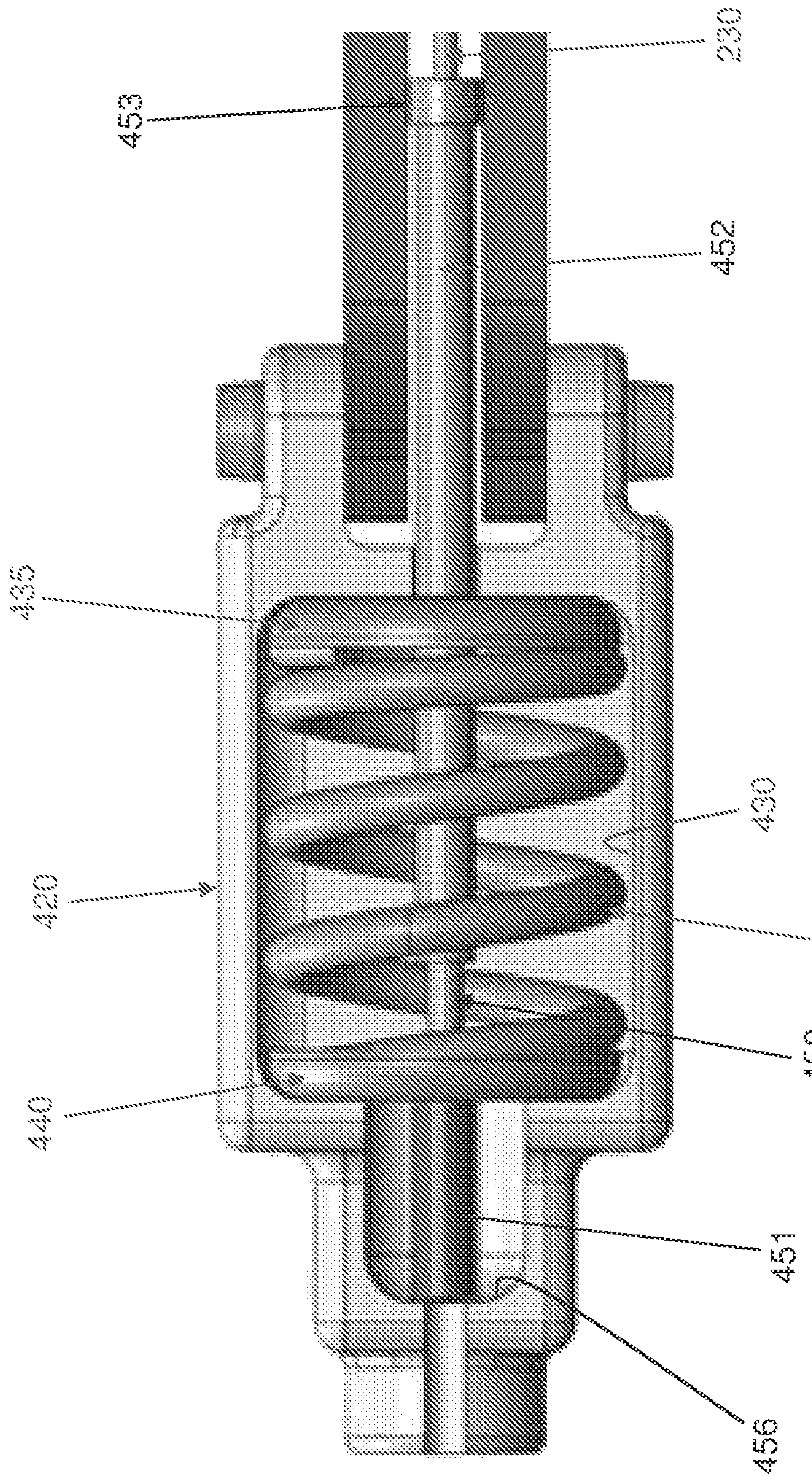


FIG. 46

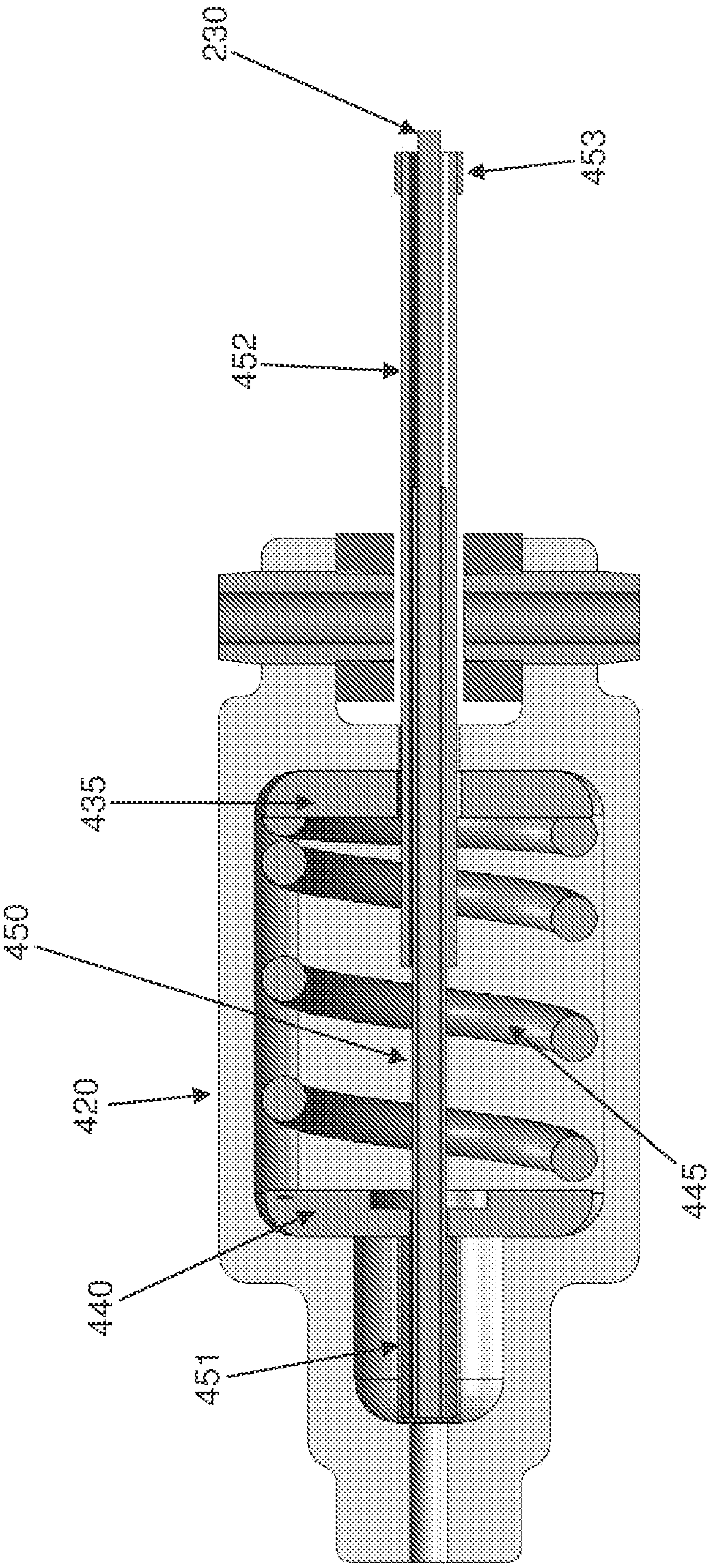


FIG. 46A

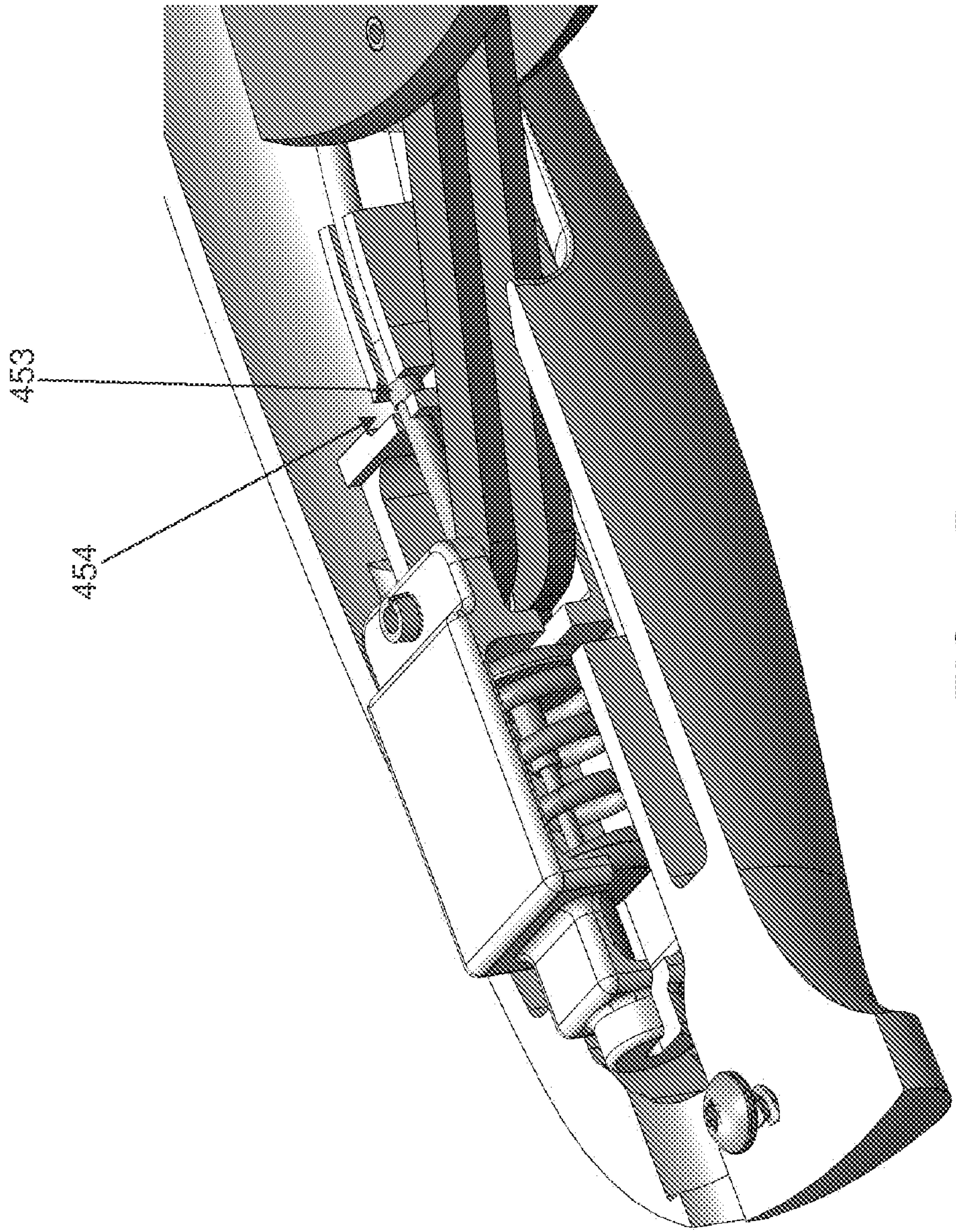


FIG. 46B

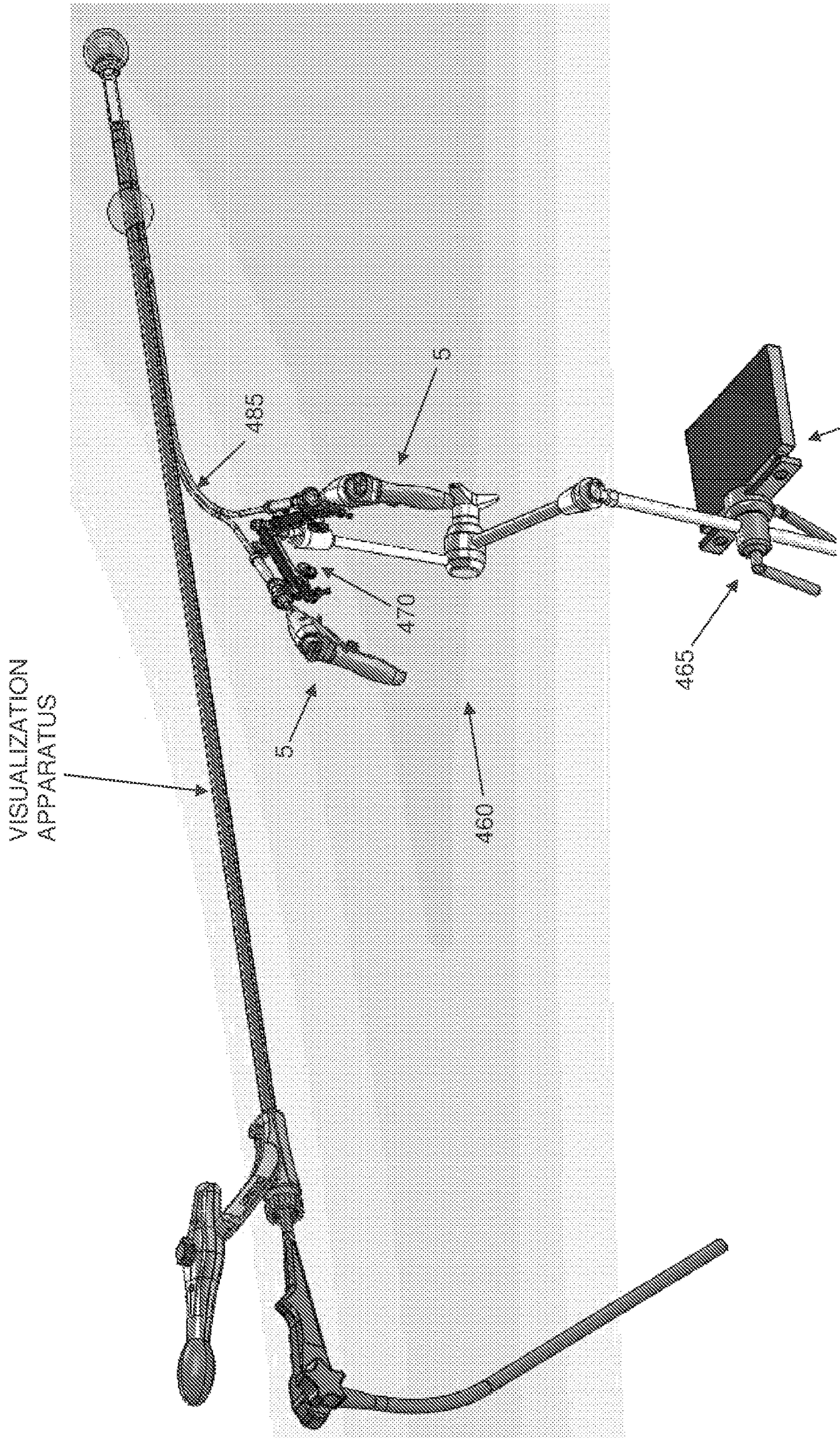


FIG. 47

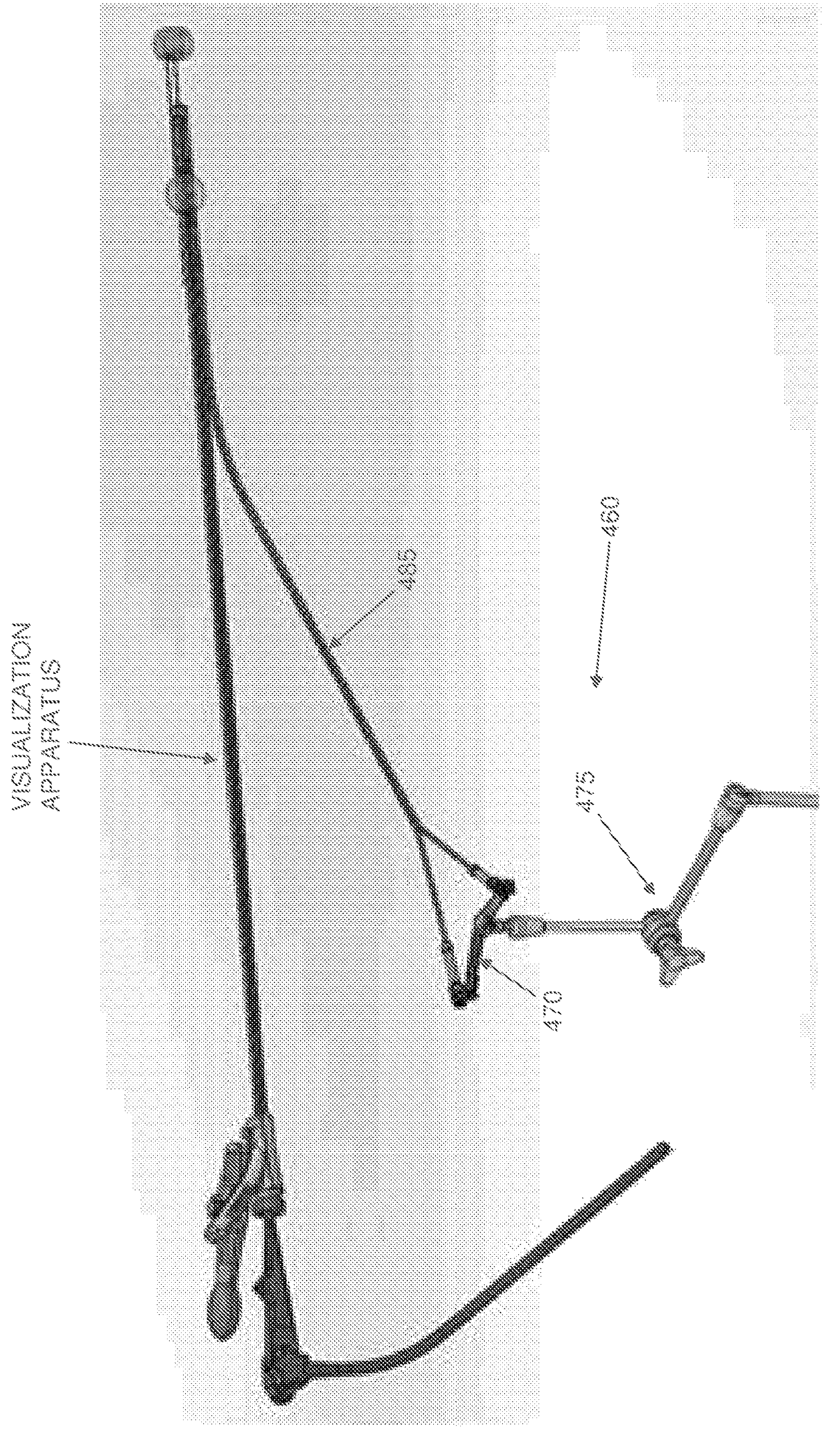


FIG. 48

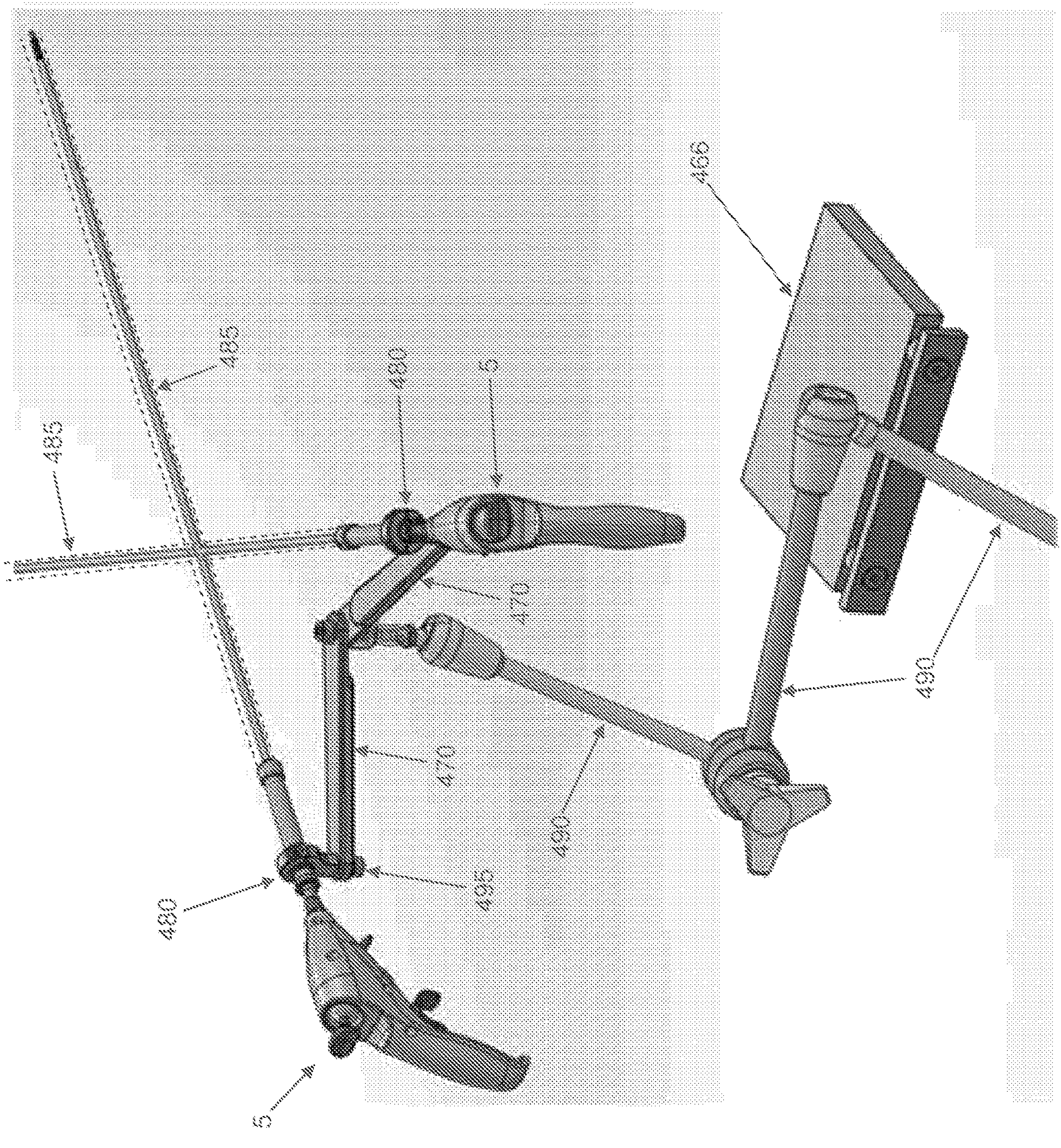


FIG. 49

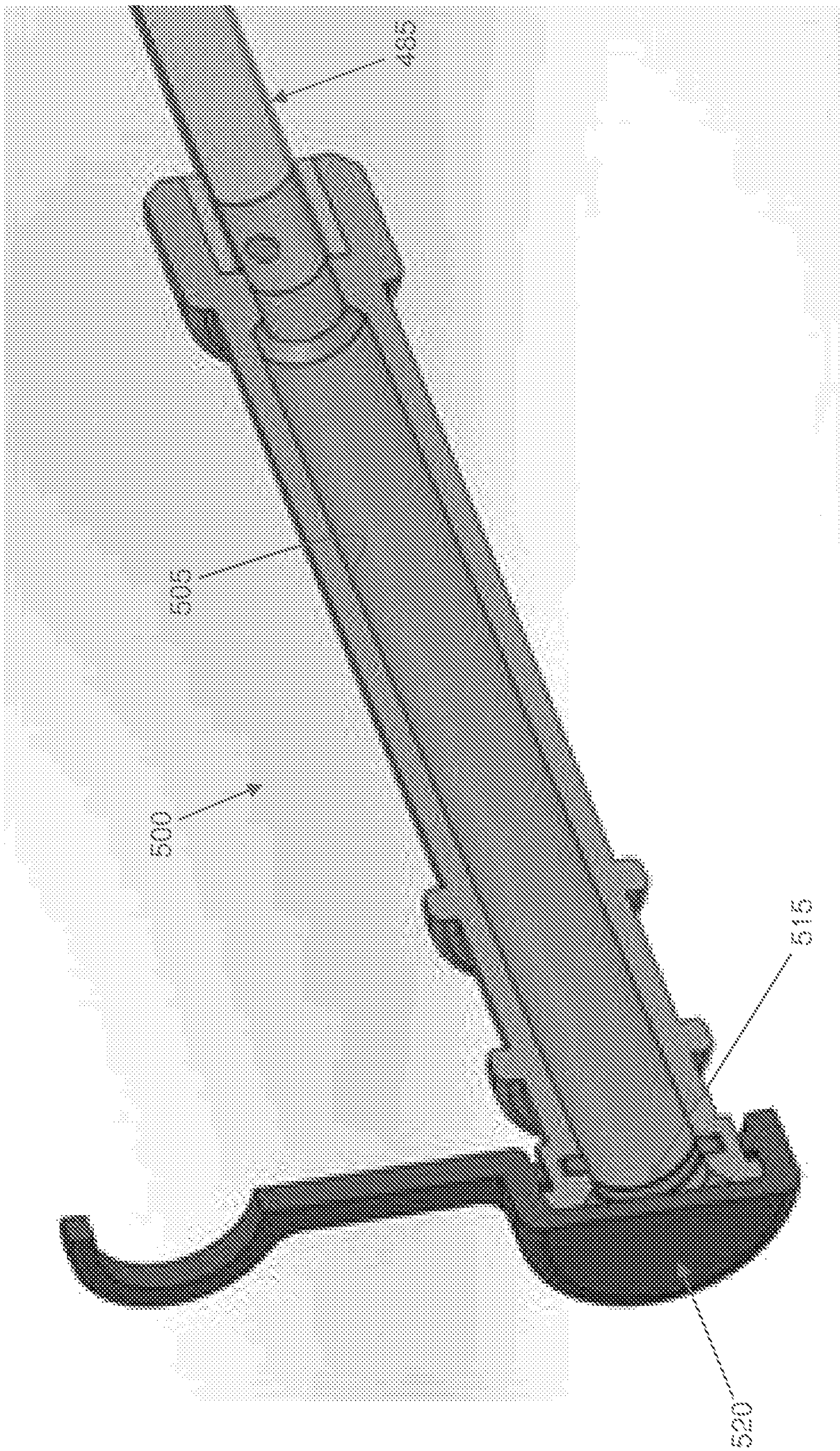


FIG. 50

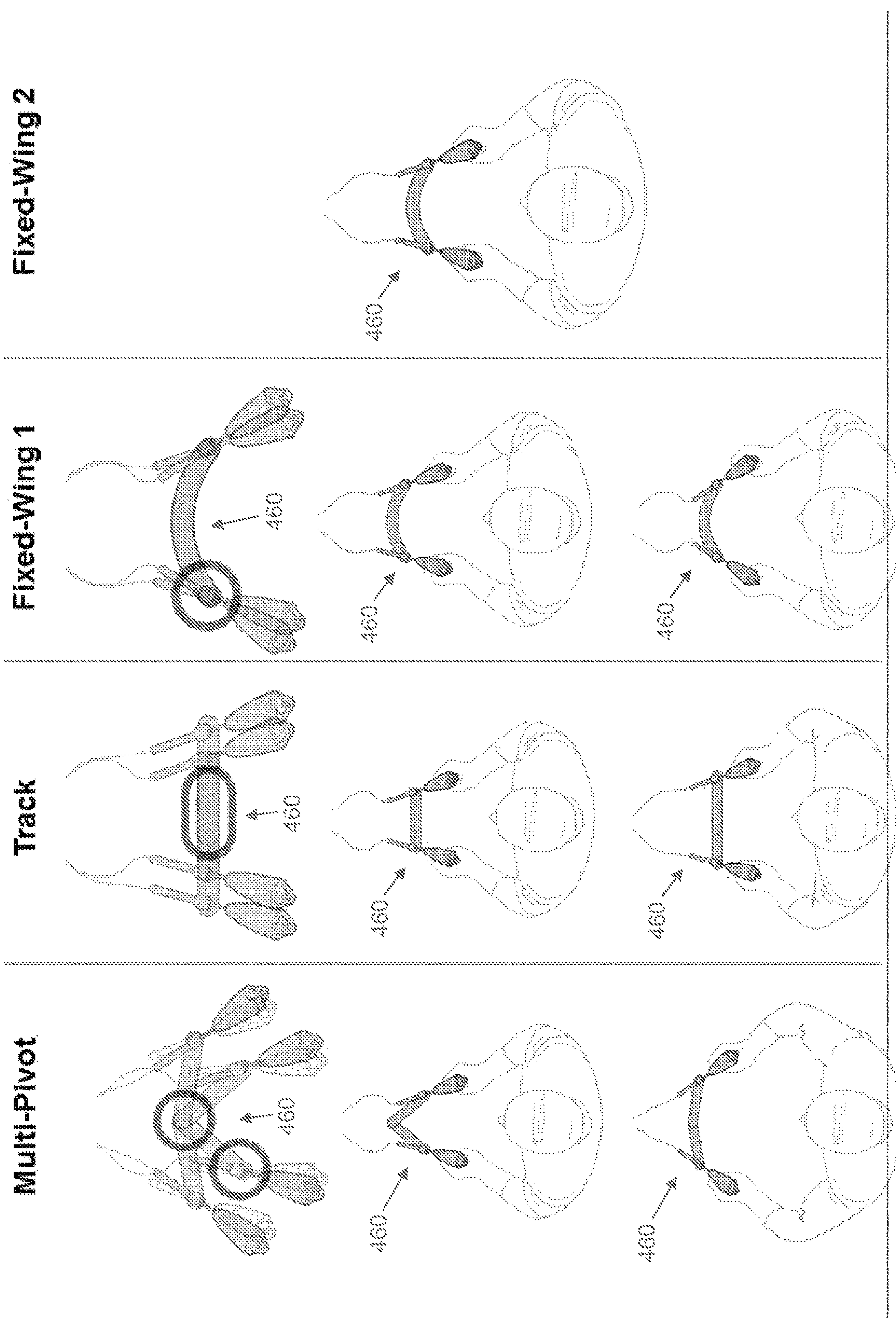
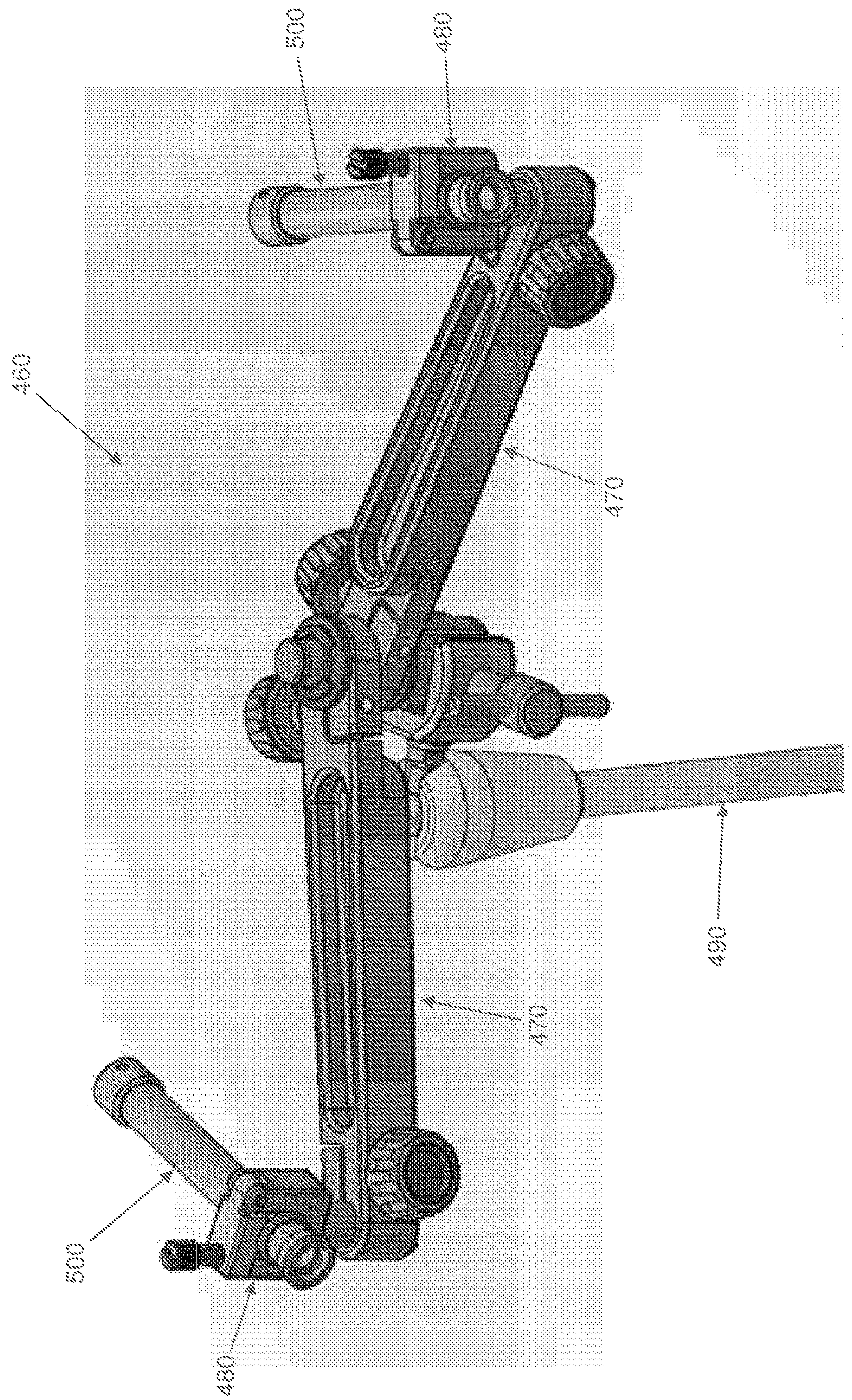


FIG. 51



Multi-Pivot

FIG. 52

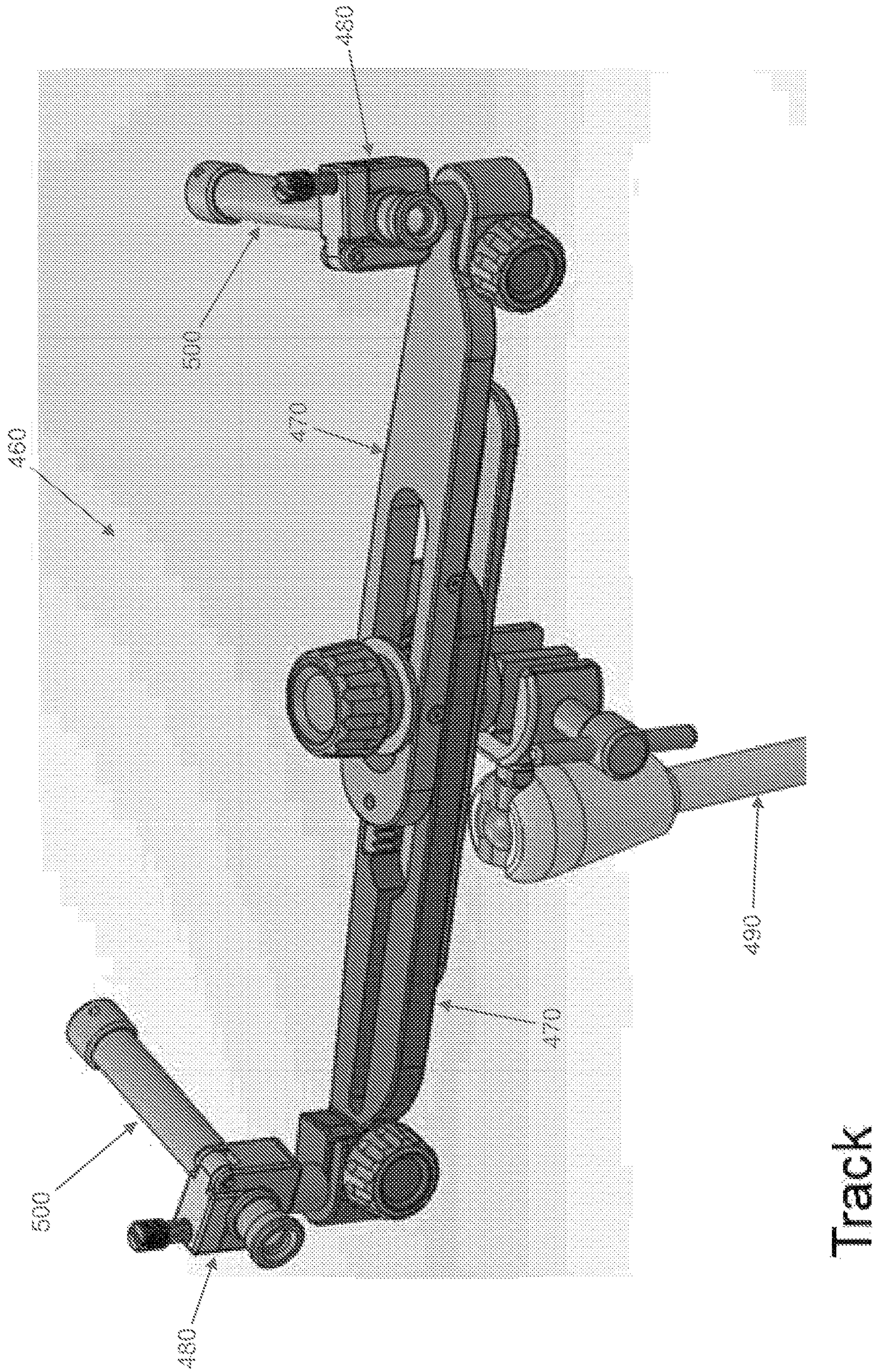
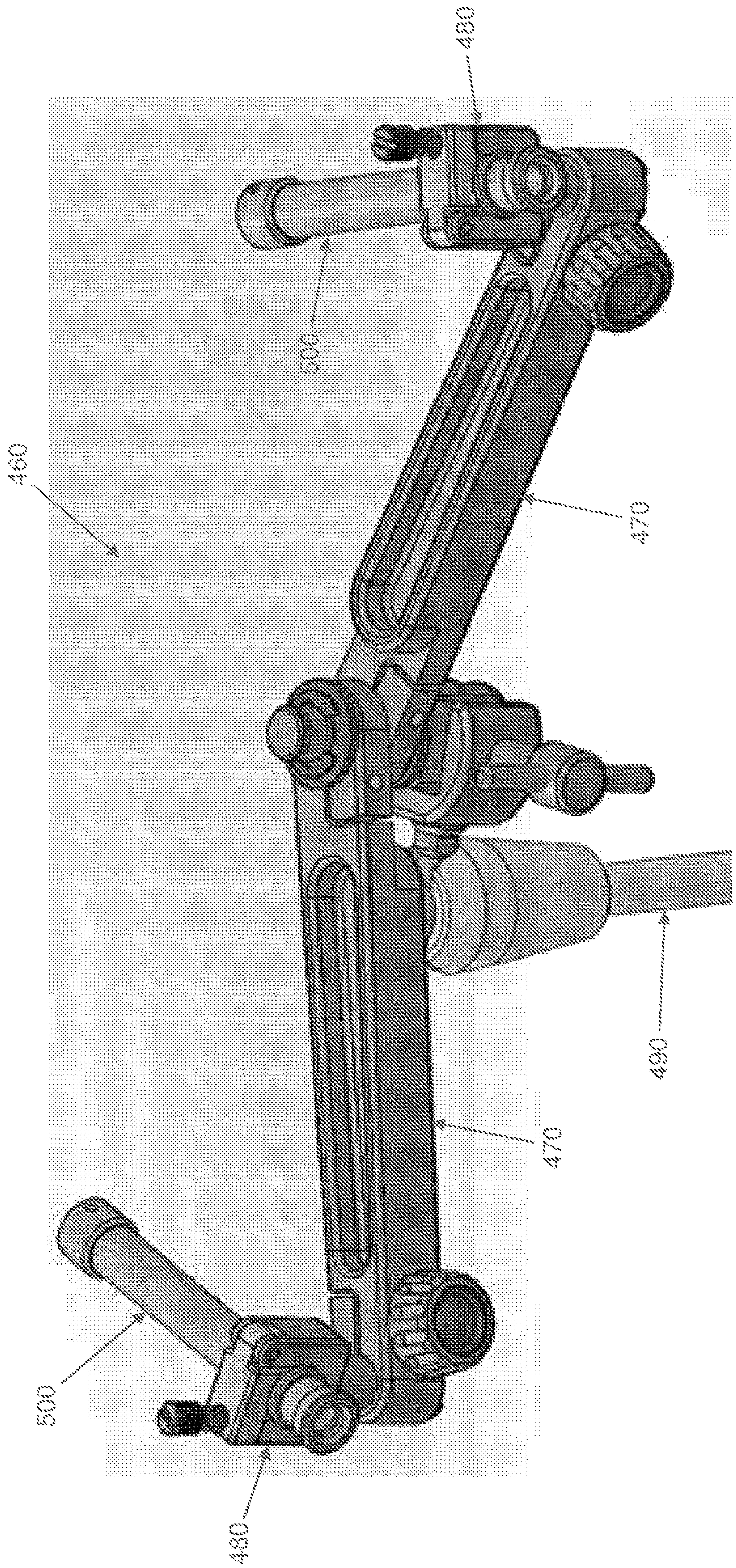


FIG. 53



Fixed Wing - 1

FIG. 54

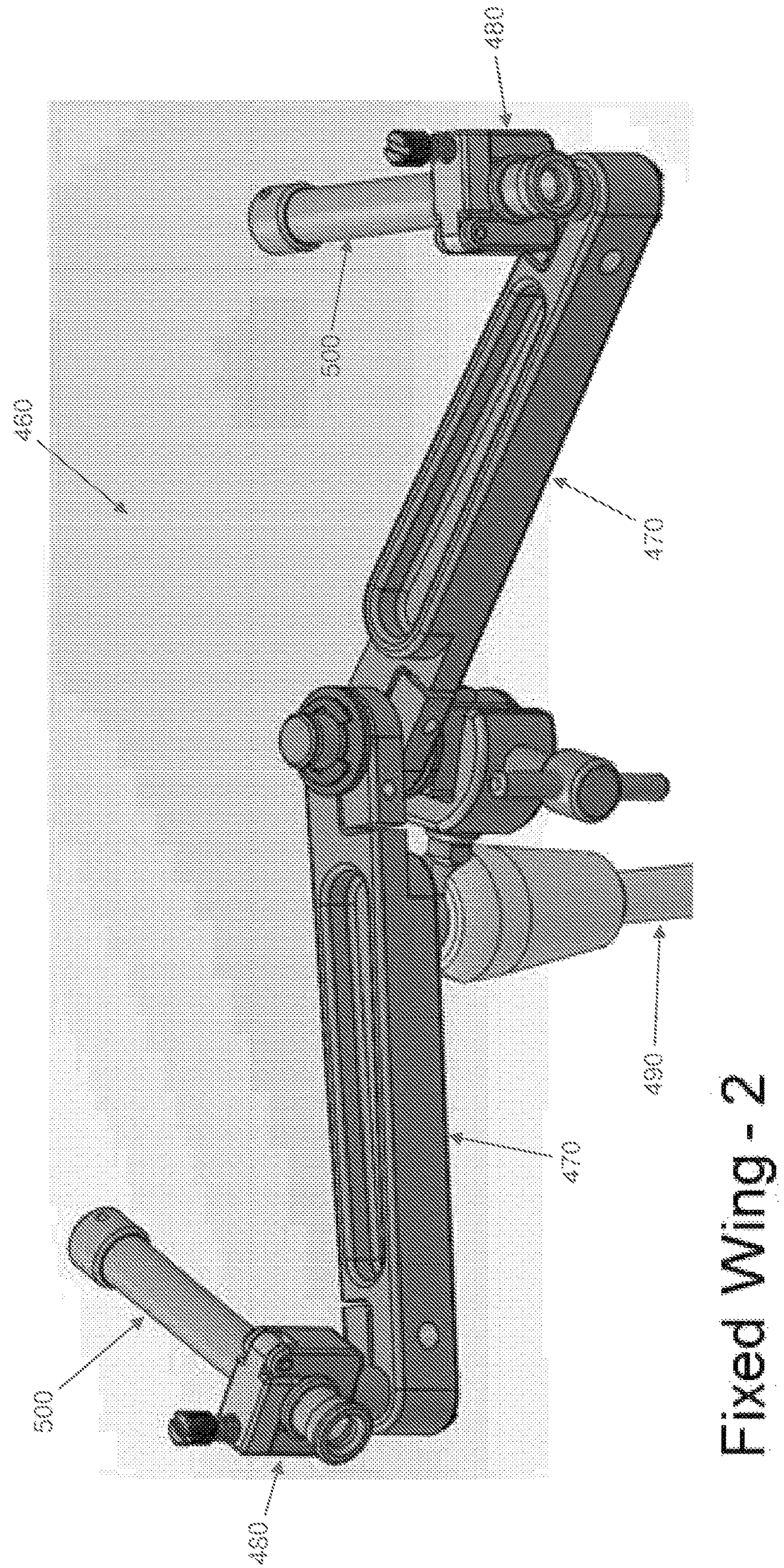


FIG. 55

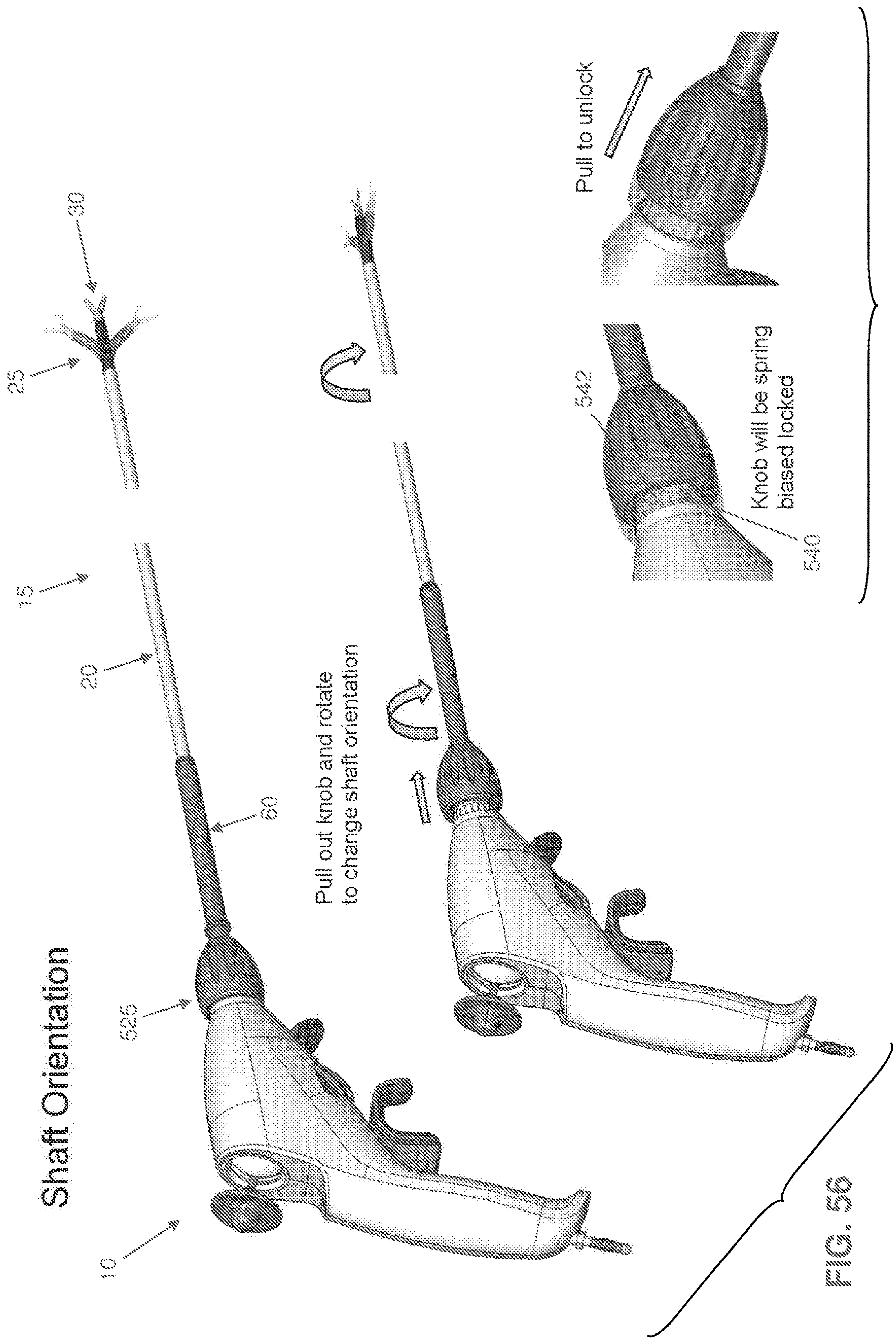

Shaft Orientation
10
525
60
20
15
25
30
Pull out knob and rotate
to change shaft orientation
542
Knob will be spring
biased locked
540
Pull to unlock

FIG. 56

FIG. 57

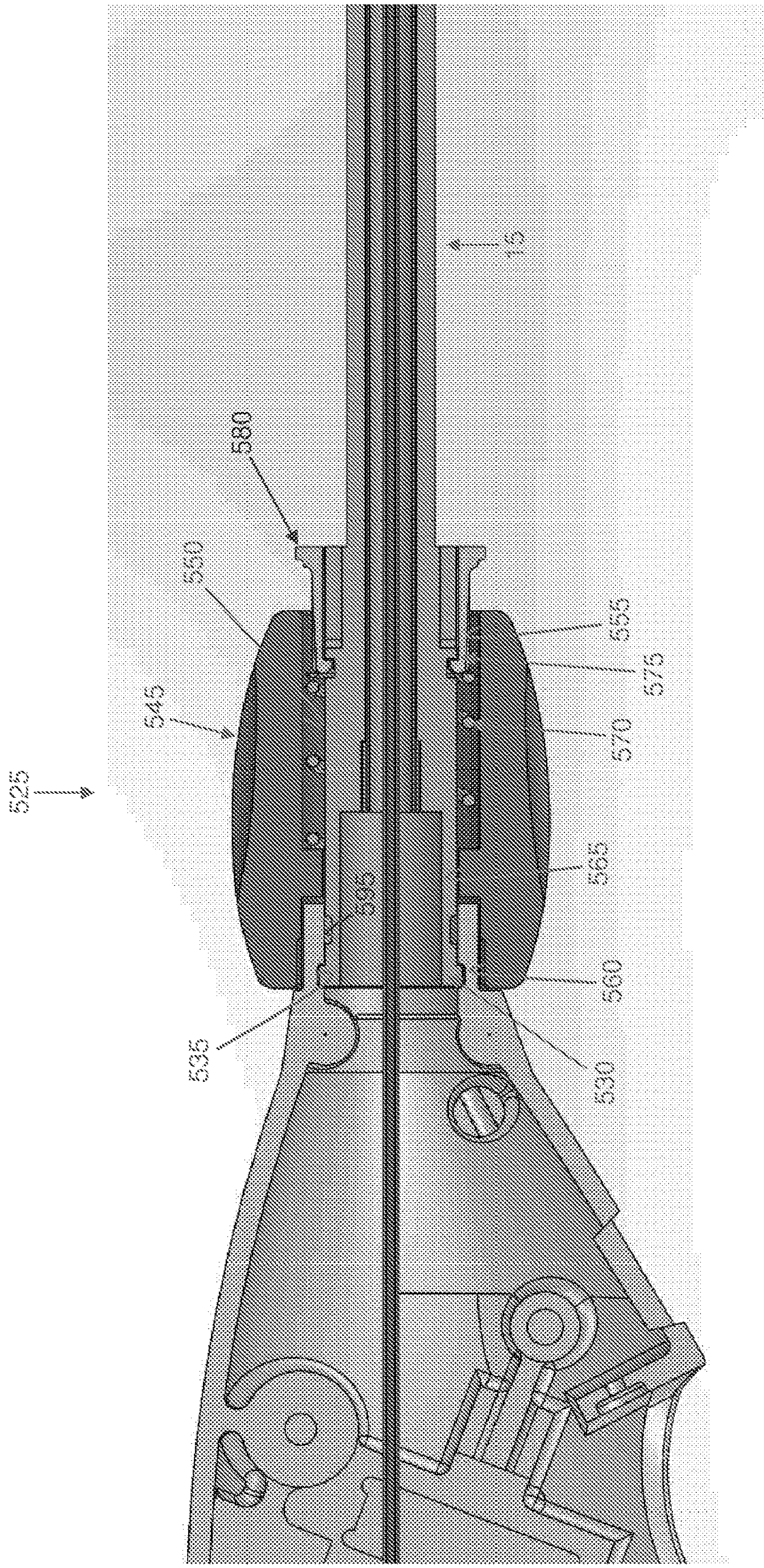


FIG. 58

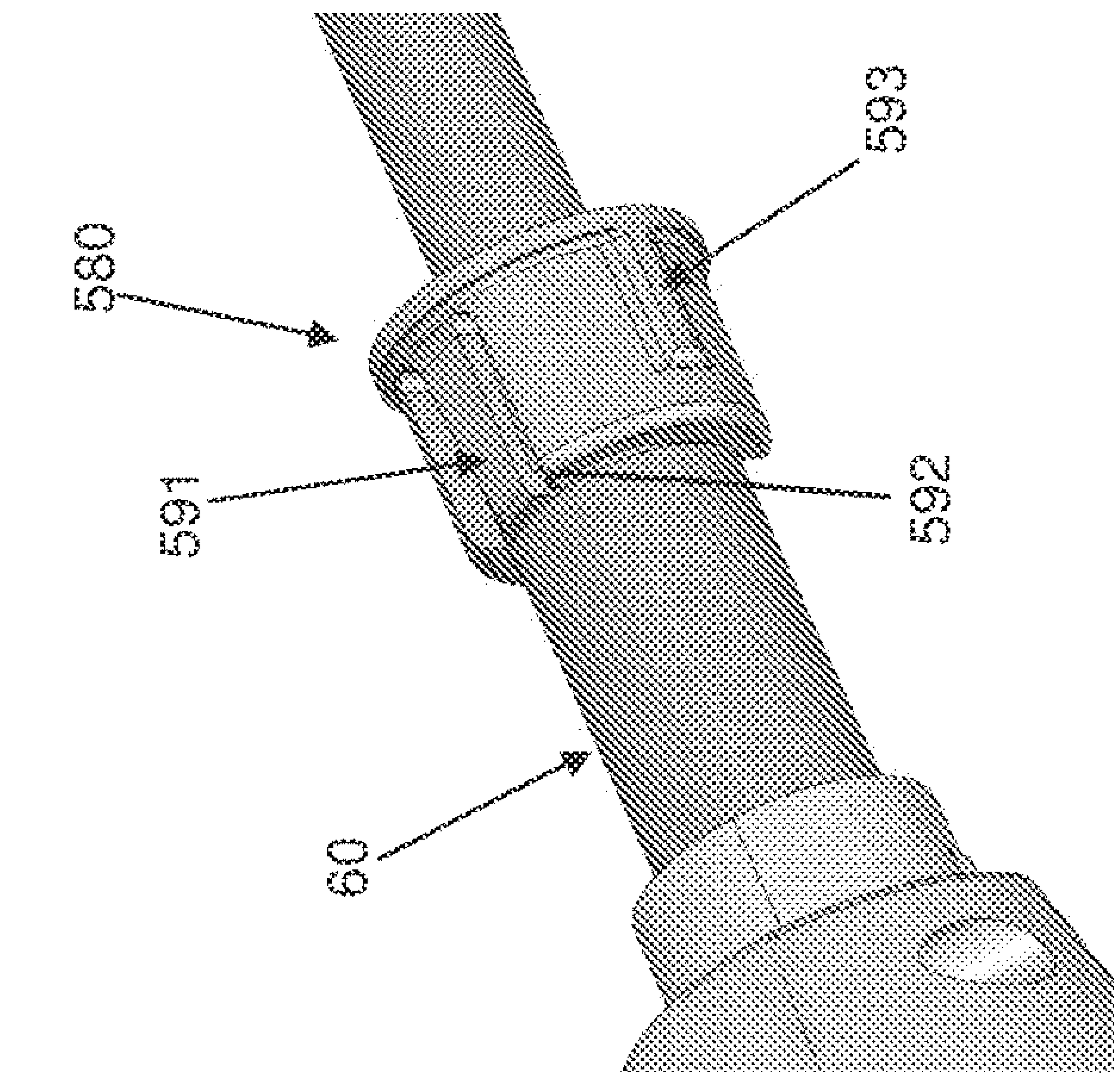


FIG. 58C

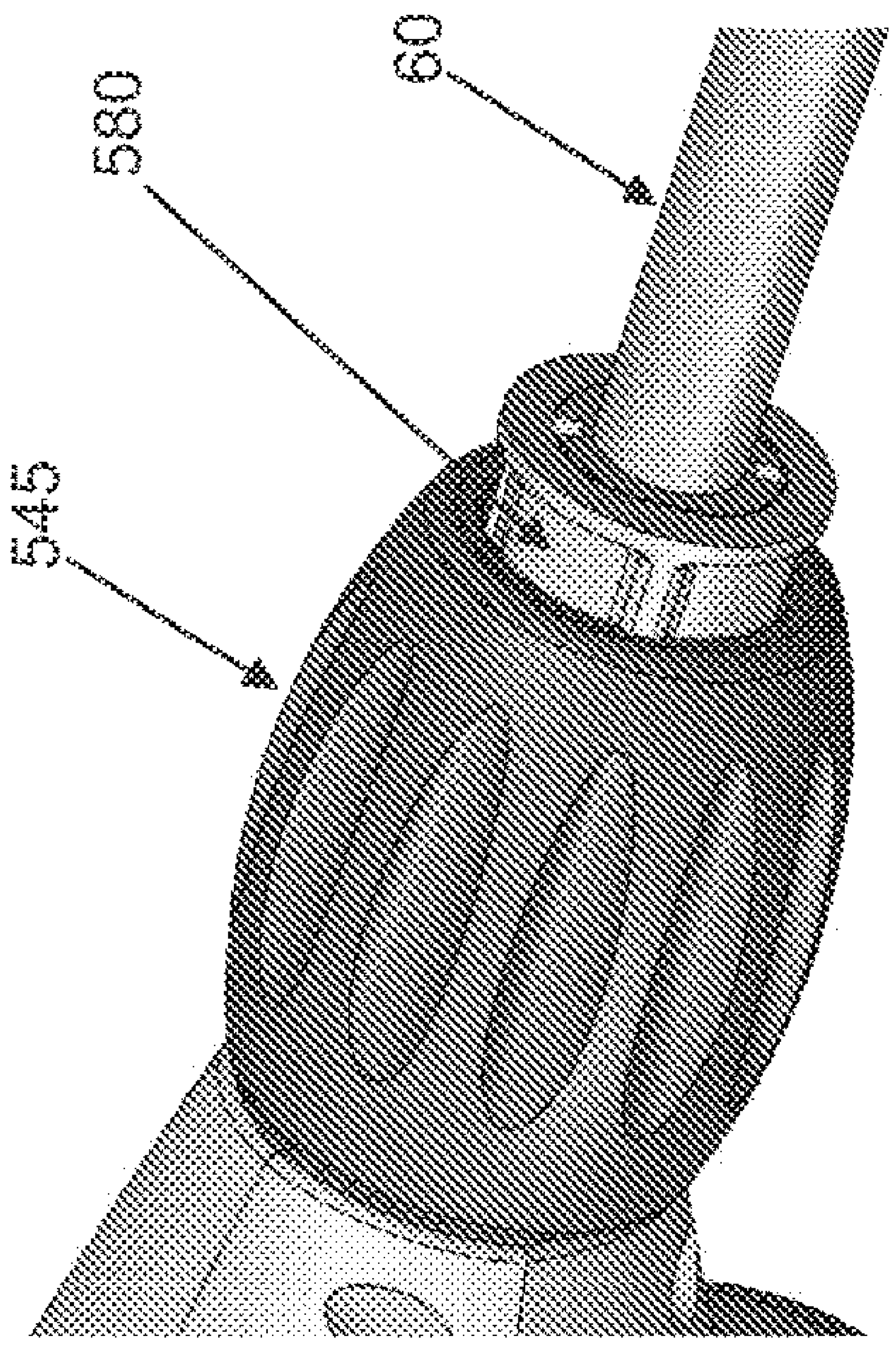


FIG. 58A

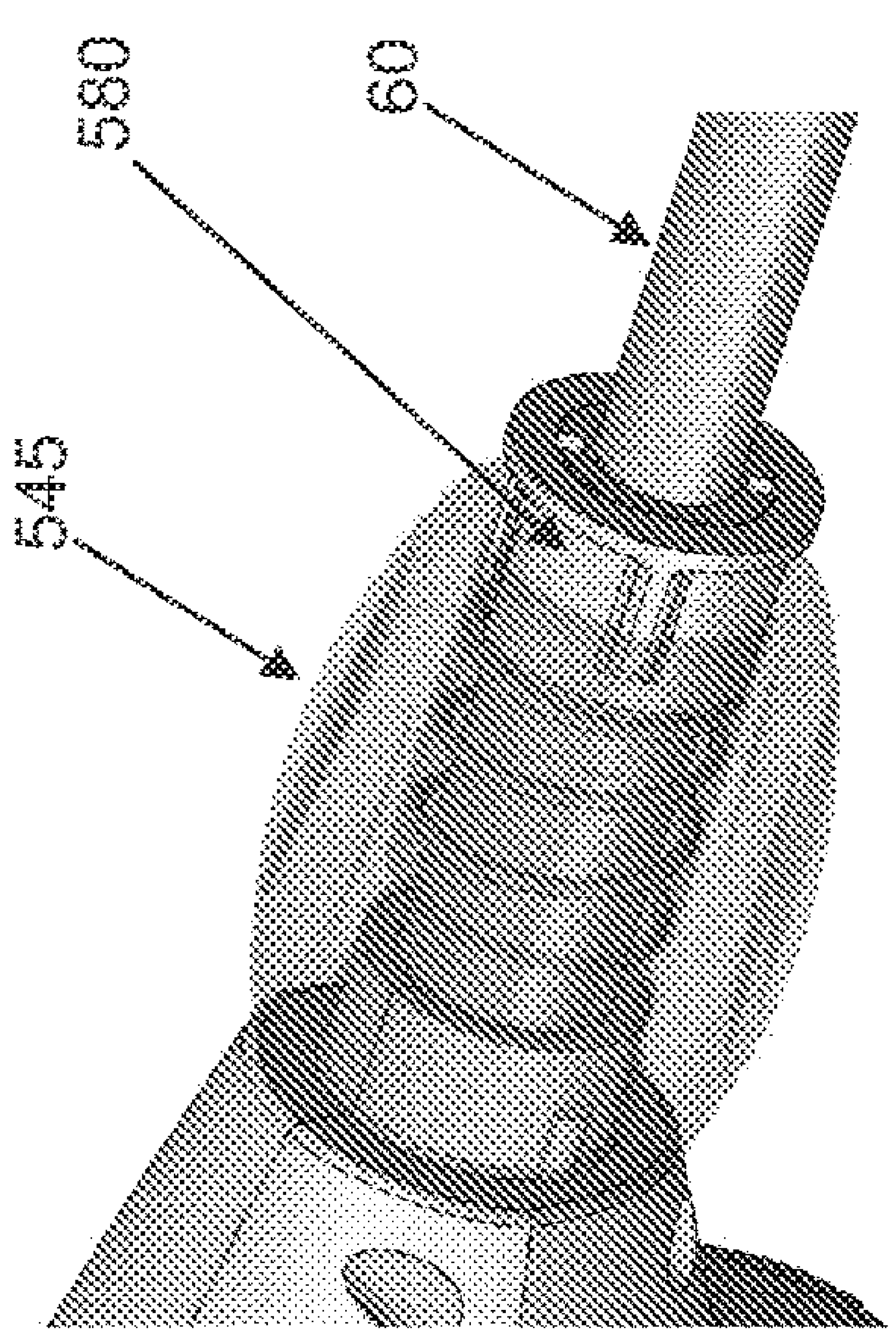


FIG. 58B

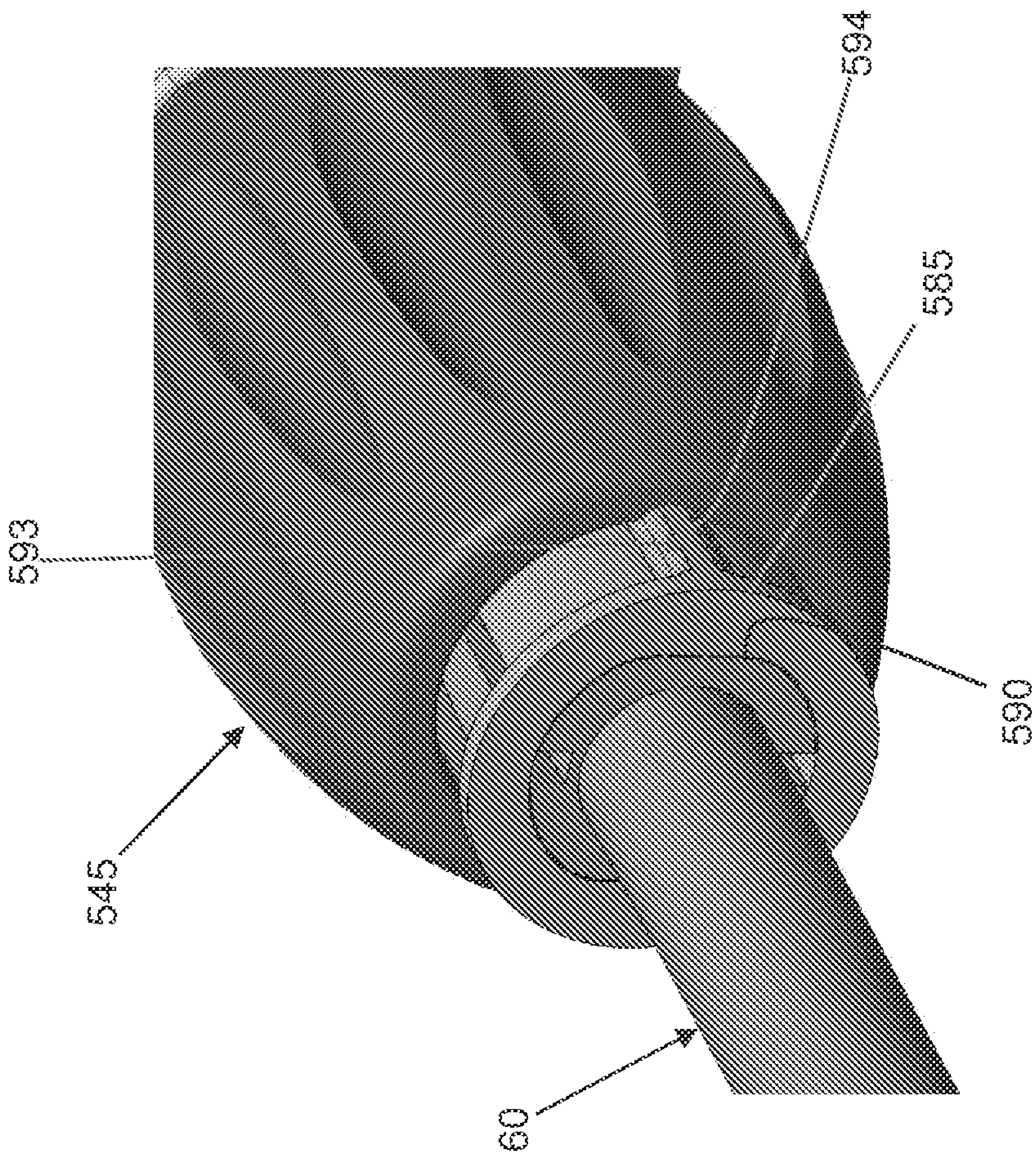


FIG. 58D

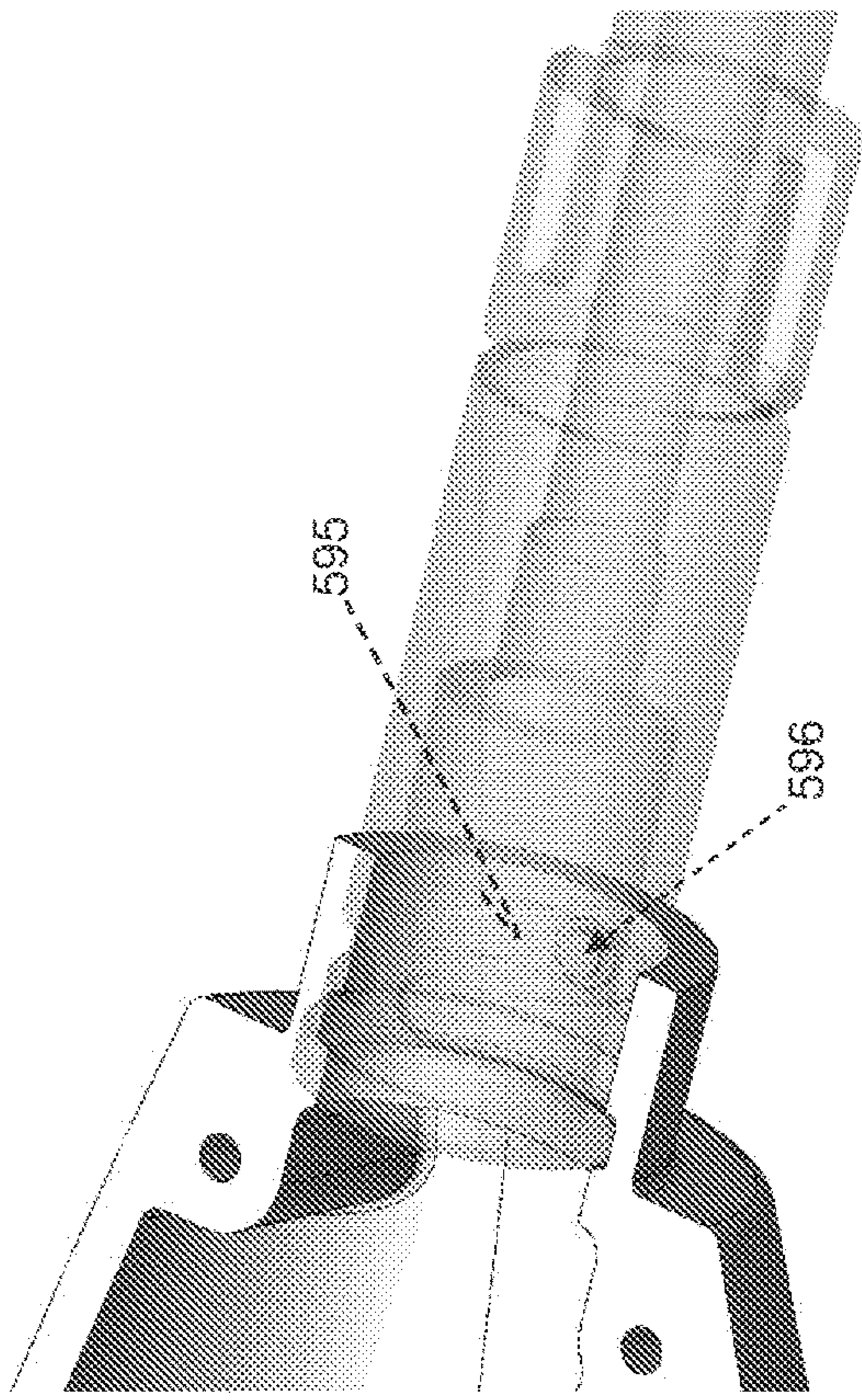


FIG. 58F

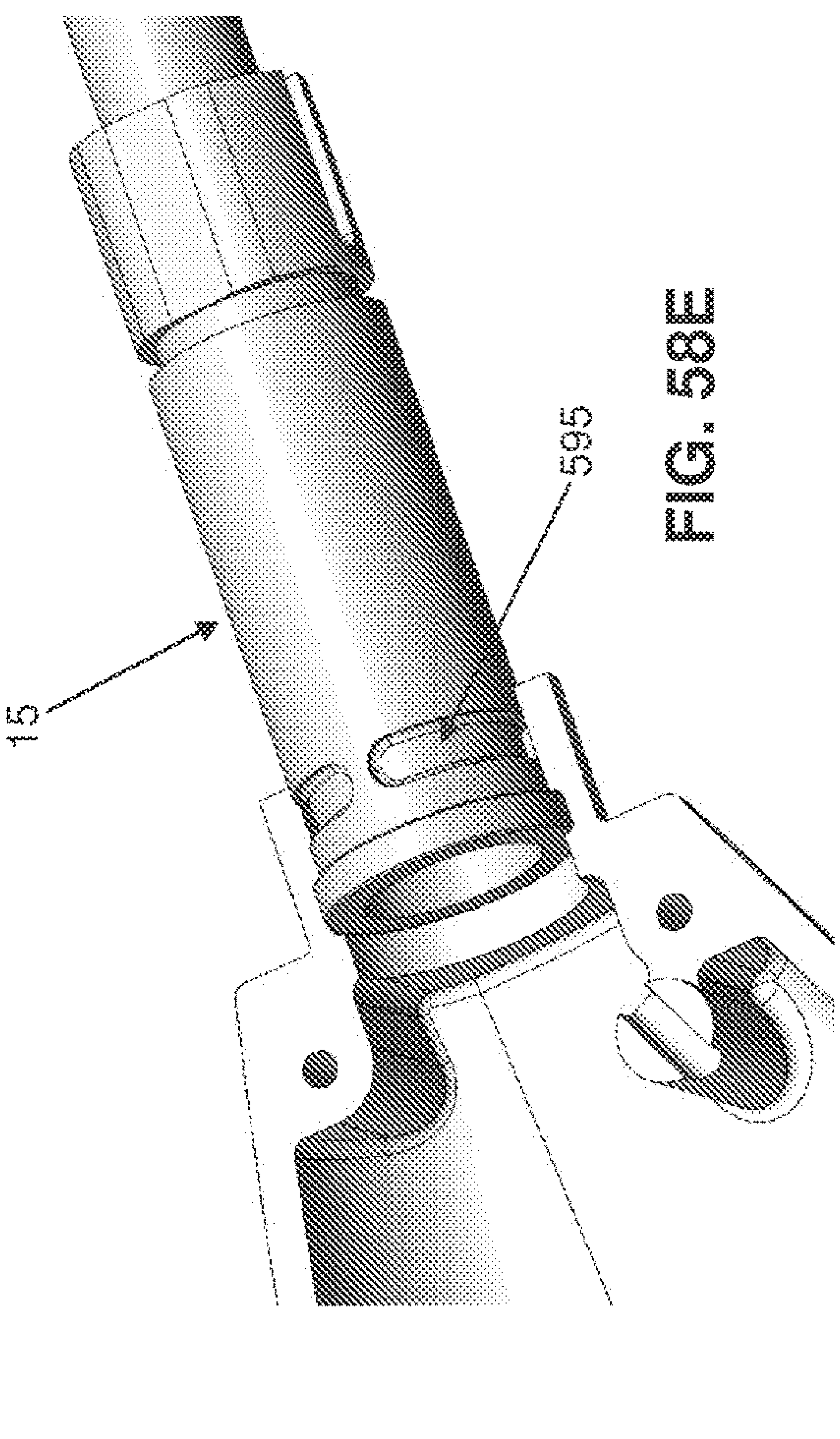


FIG. 58E

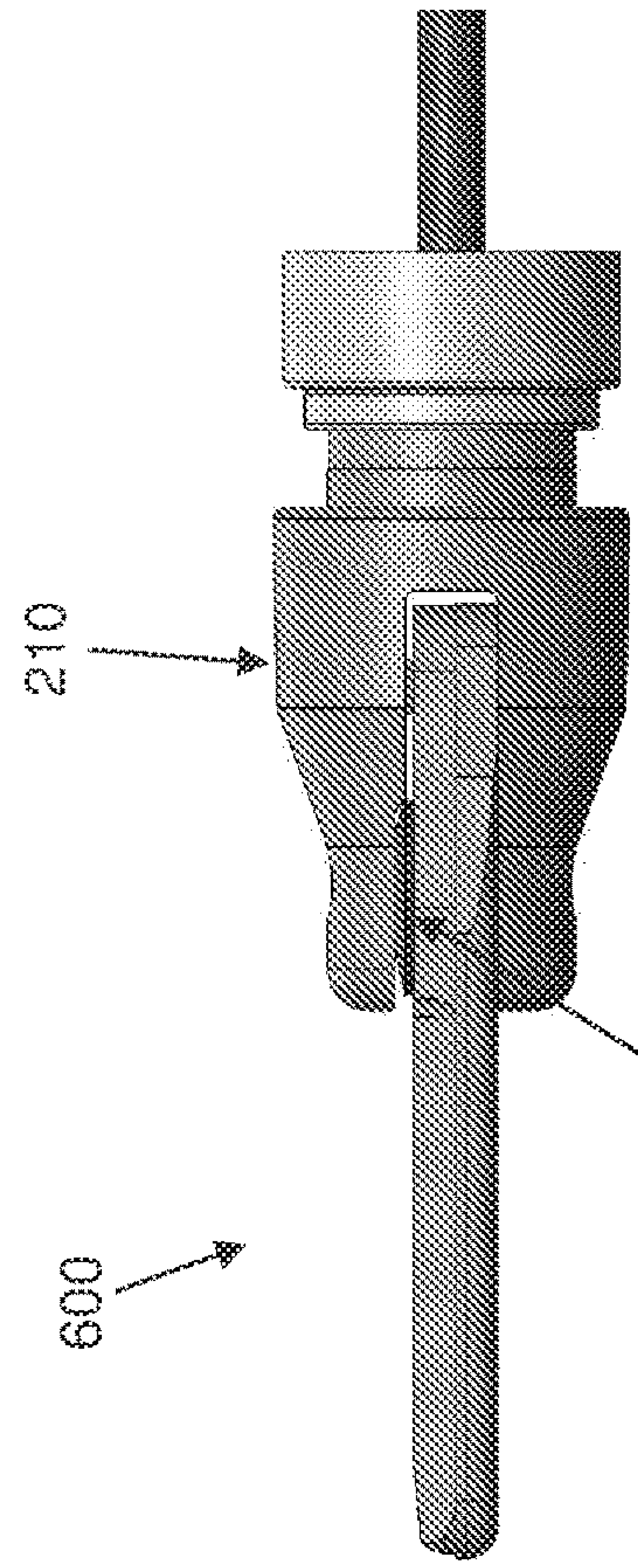


FIG. 62

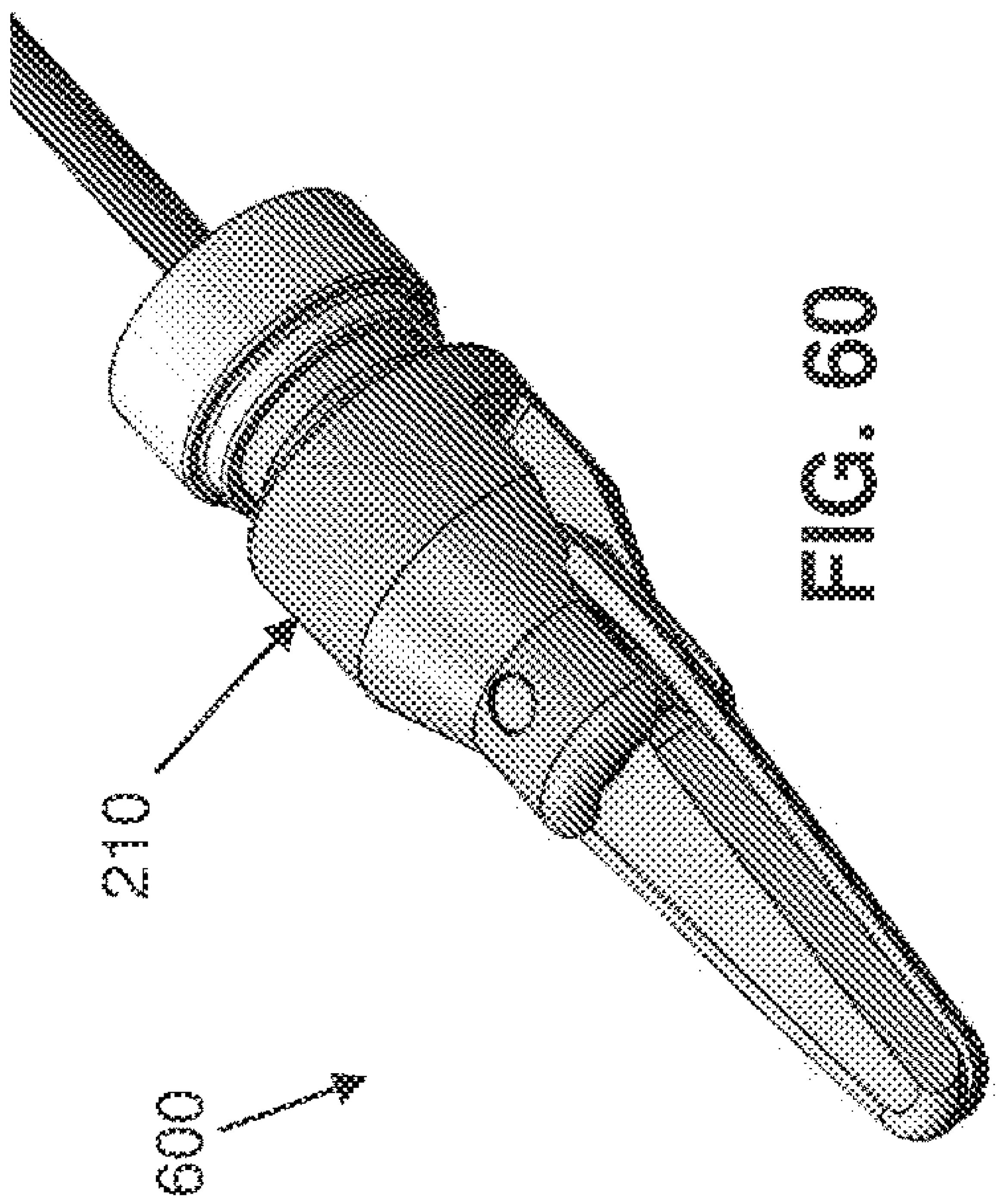


FIG. 60

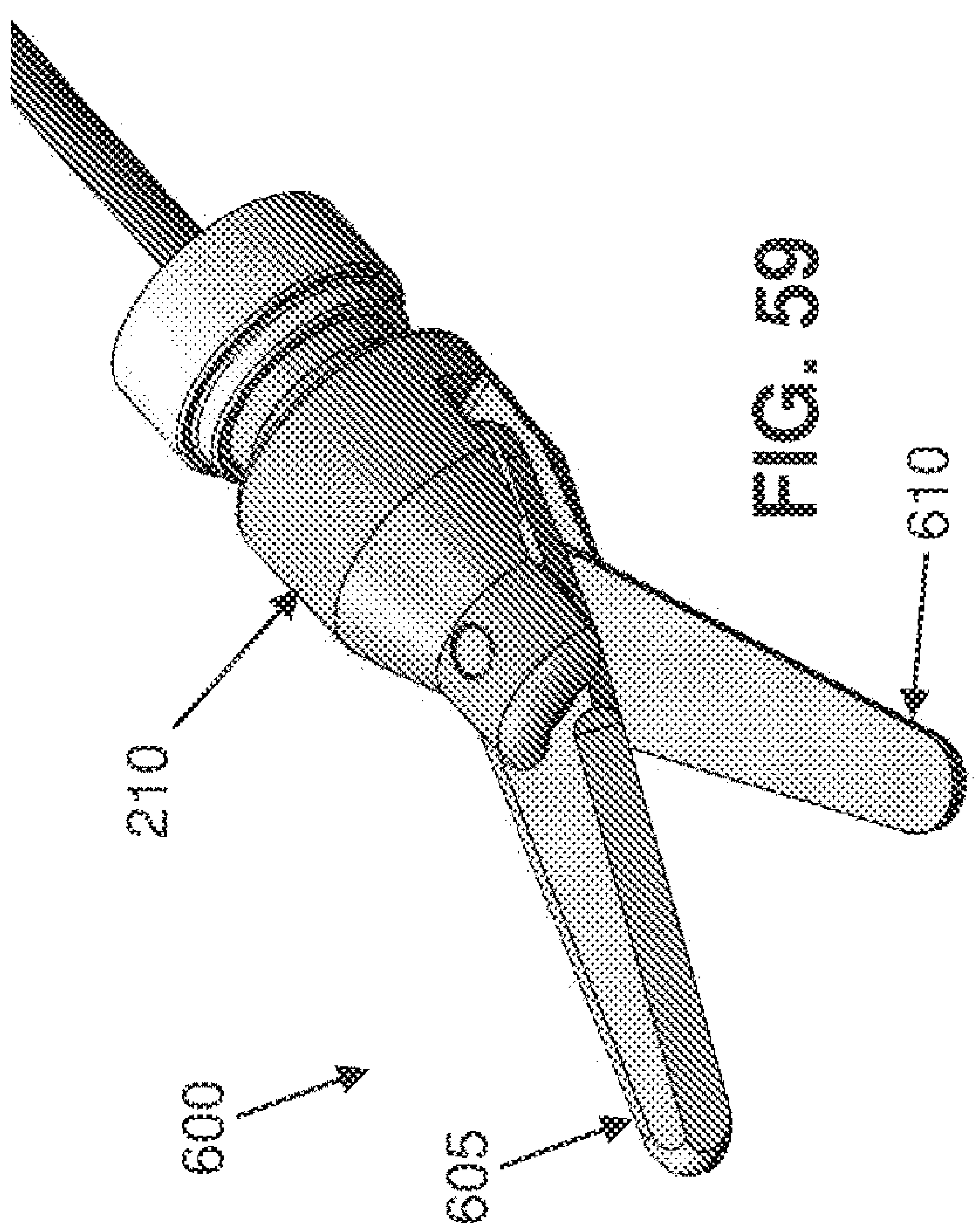


FIG. 59

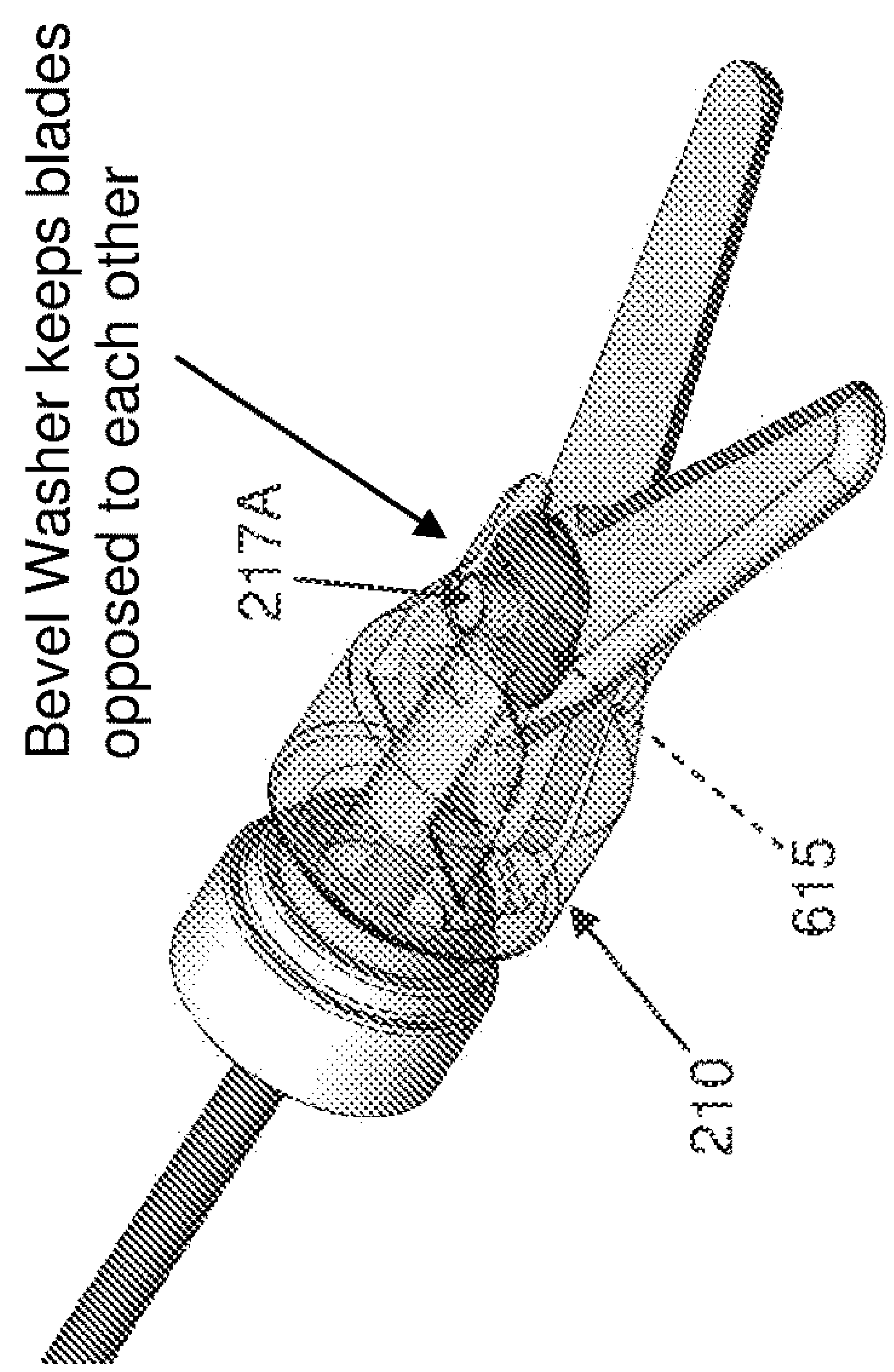


FIG. 61

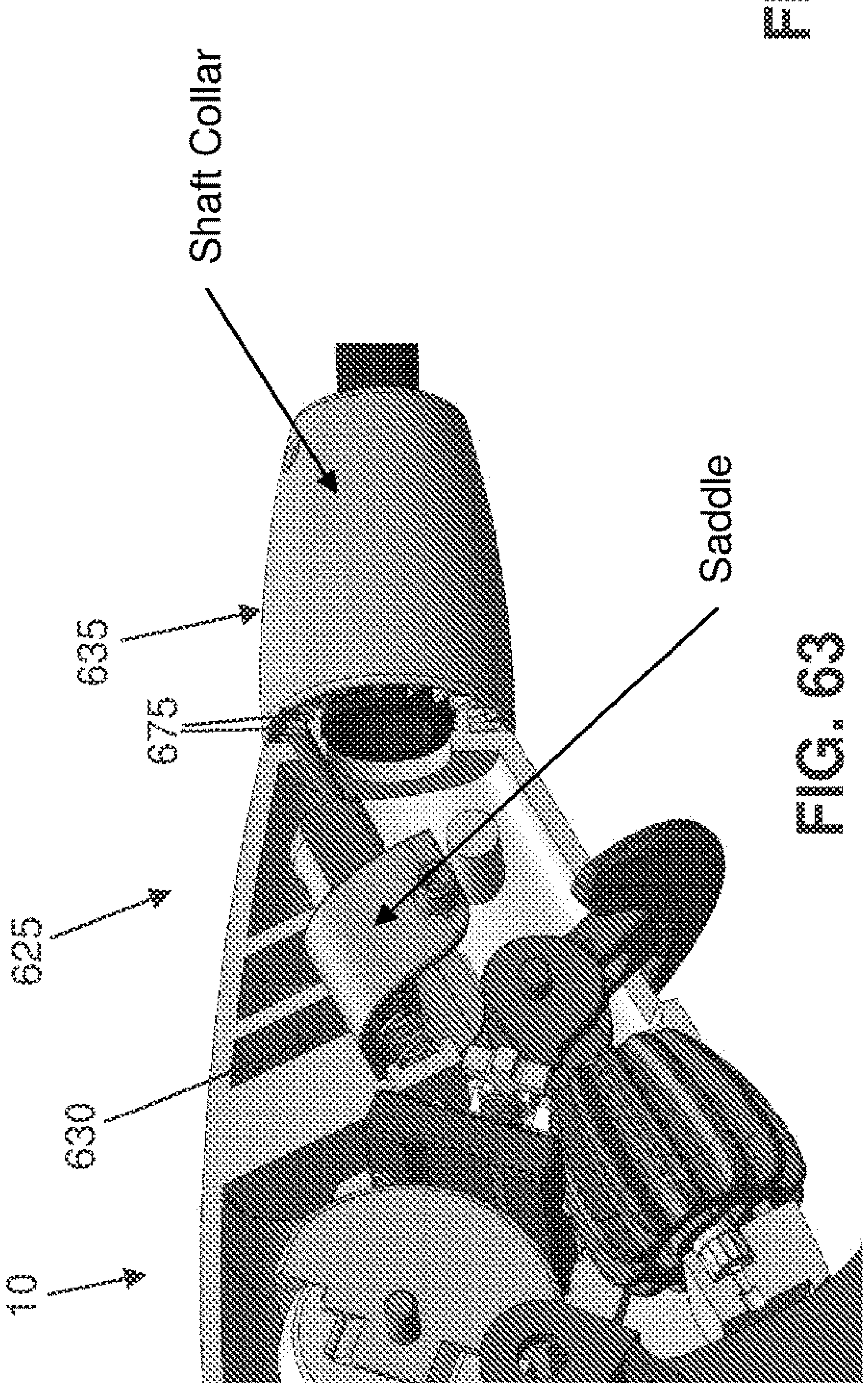


FIG. 63

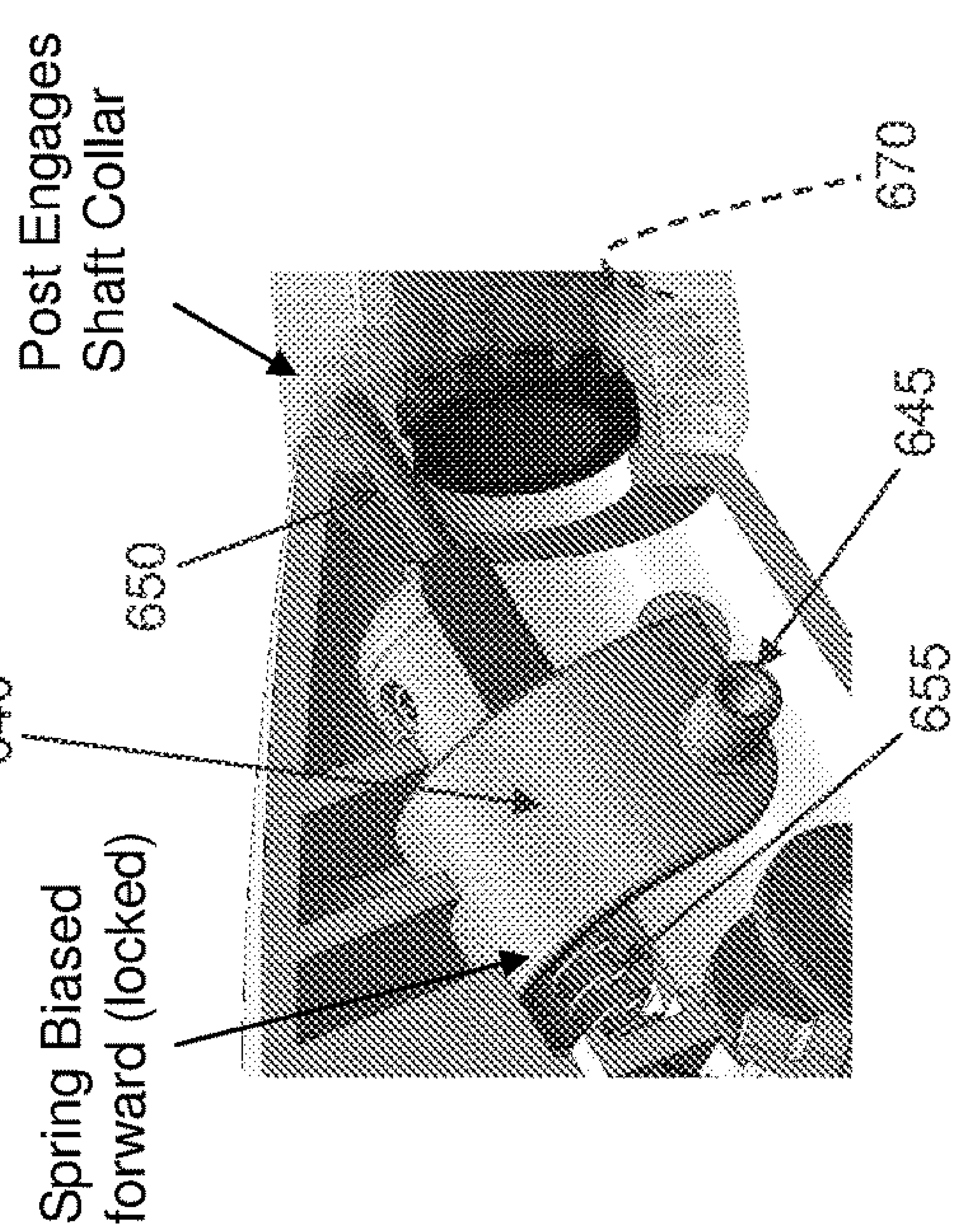


FIG. 64

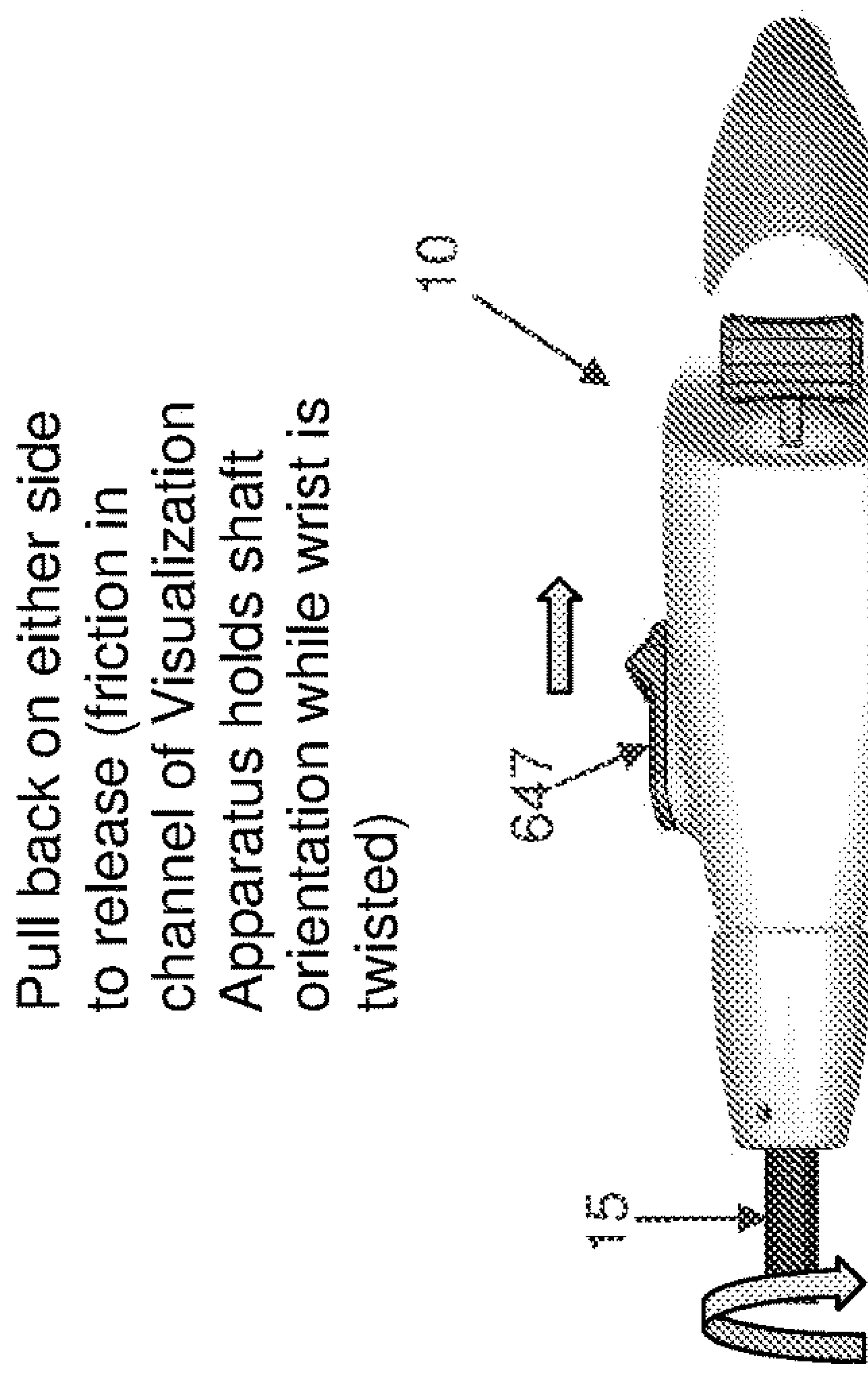


FIG. 65

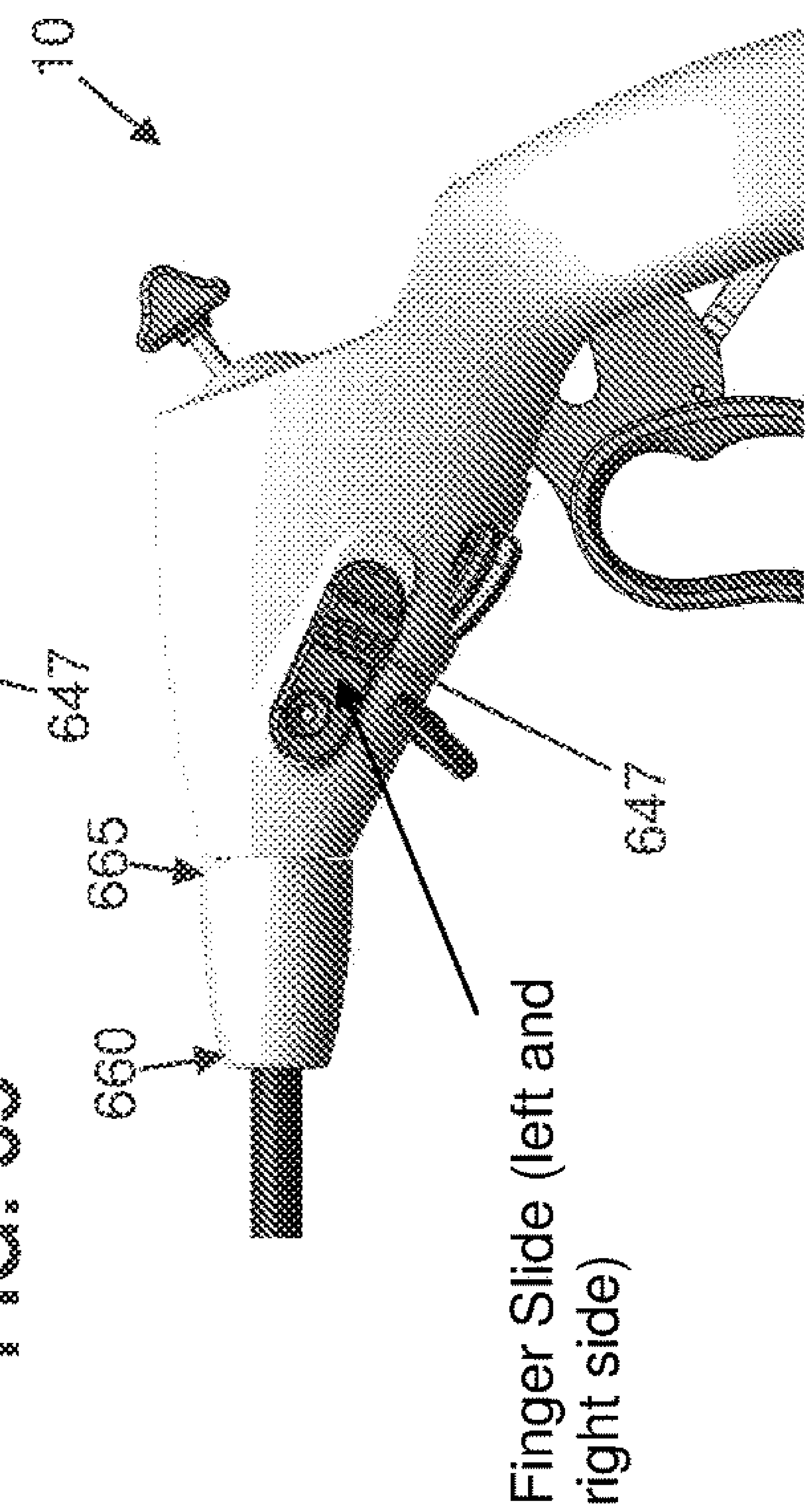


FIG. 66

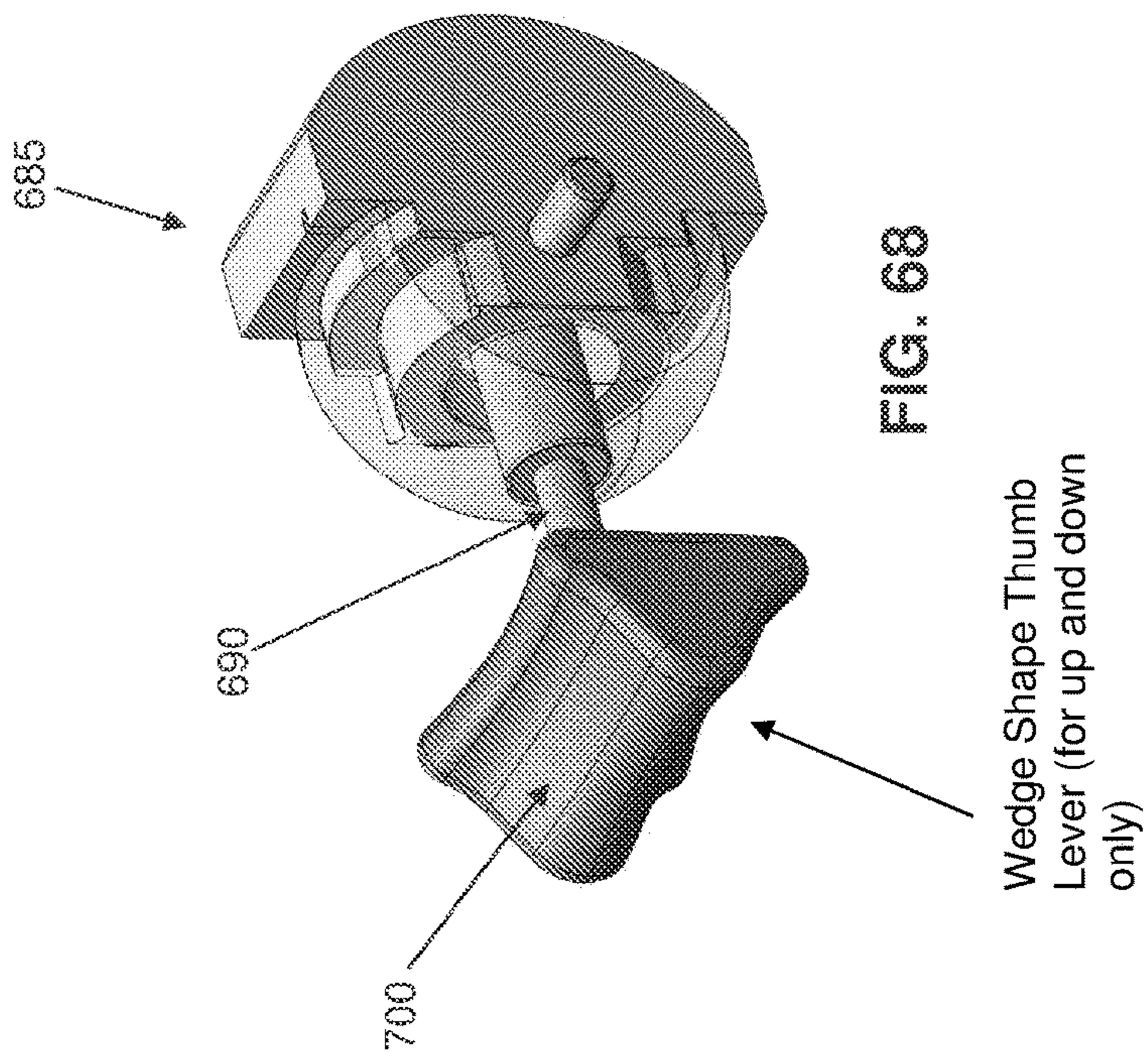


FIG. 68

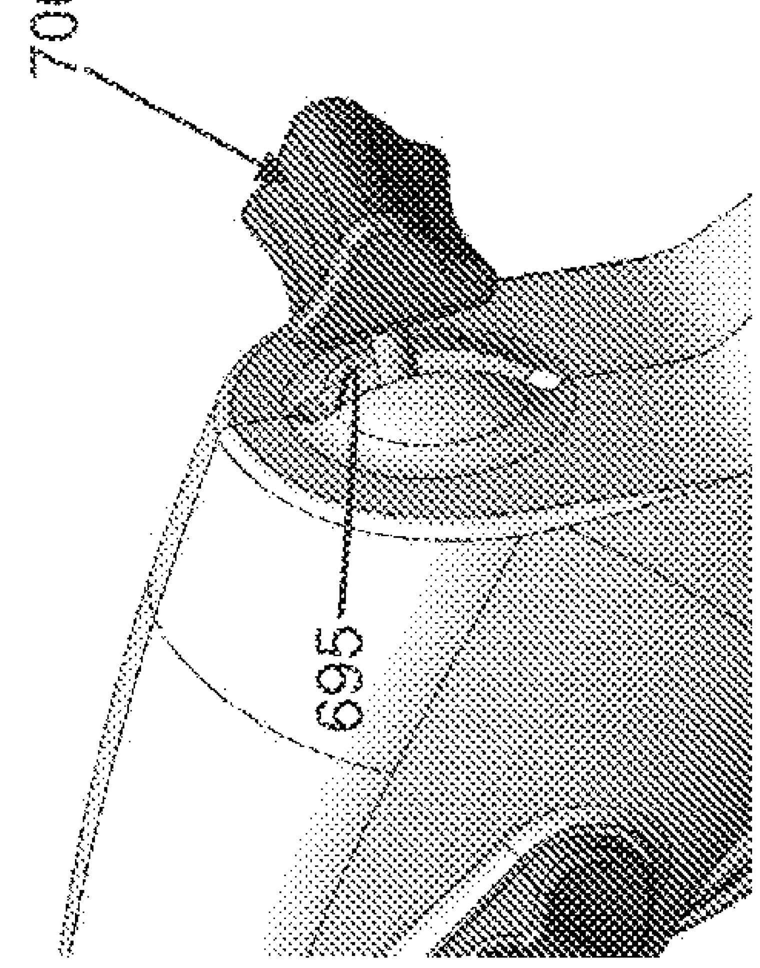


FIG. 69

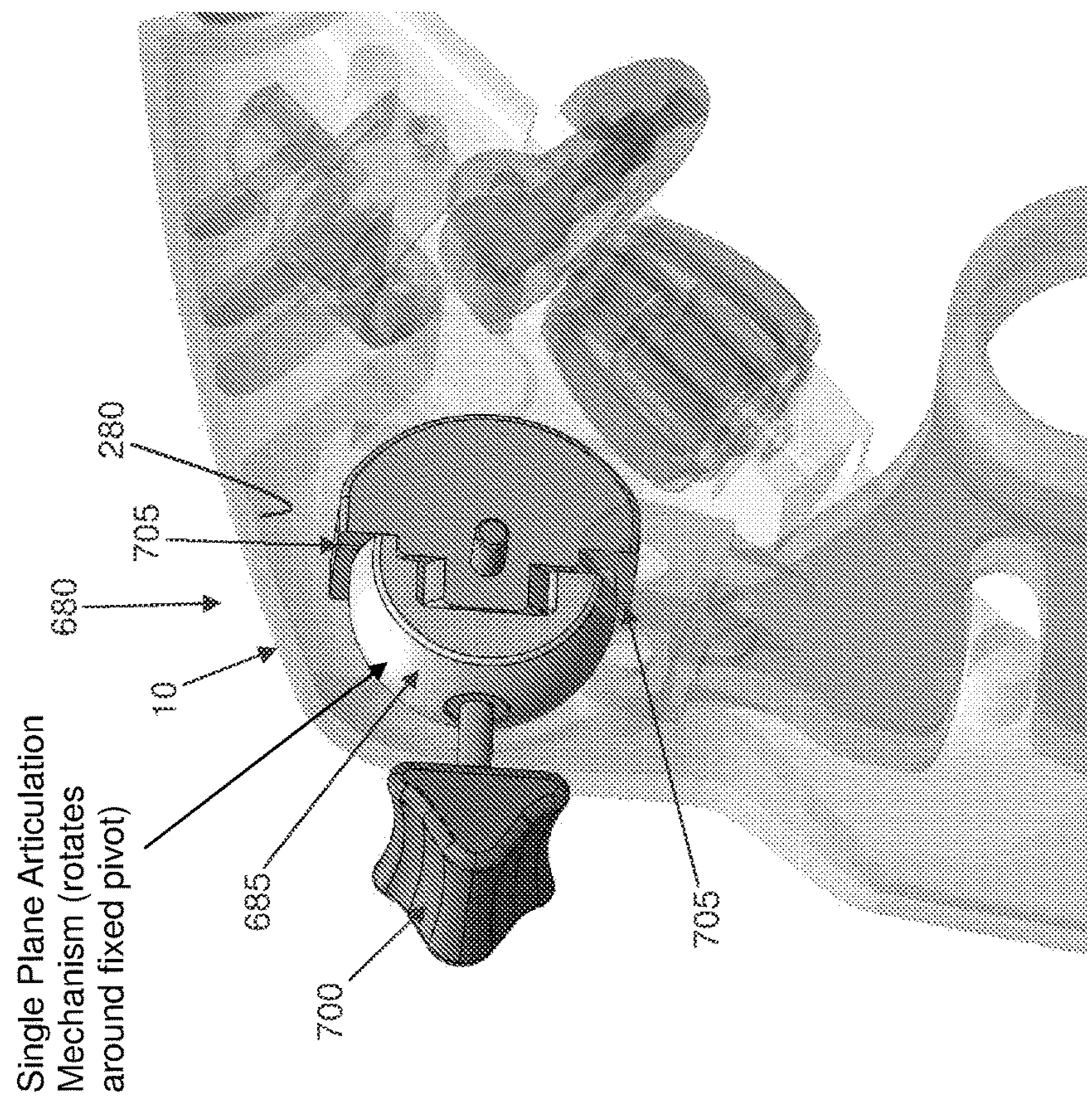


FIG. 67

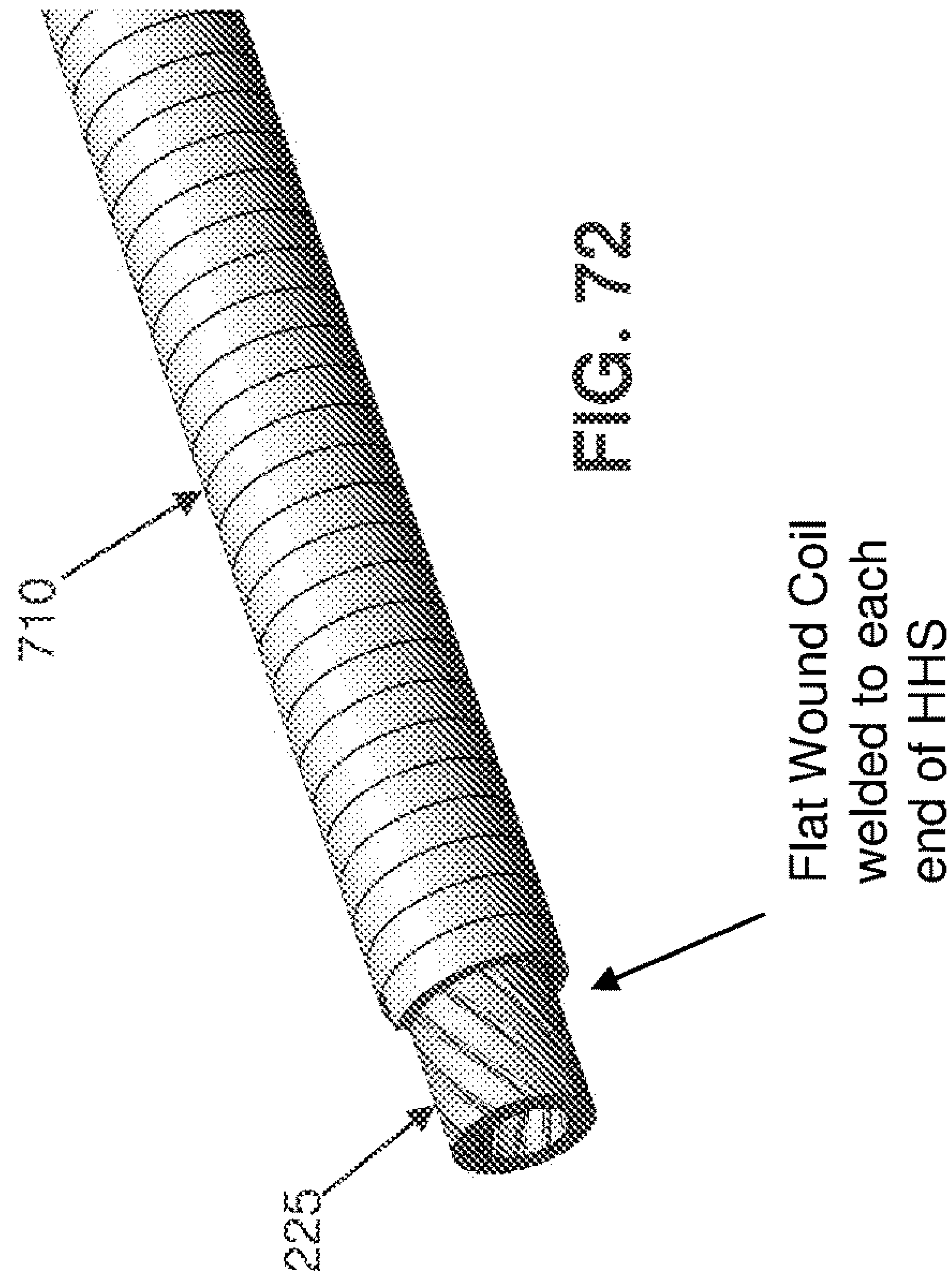


FIG. 72

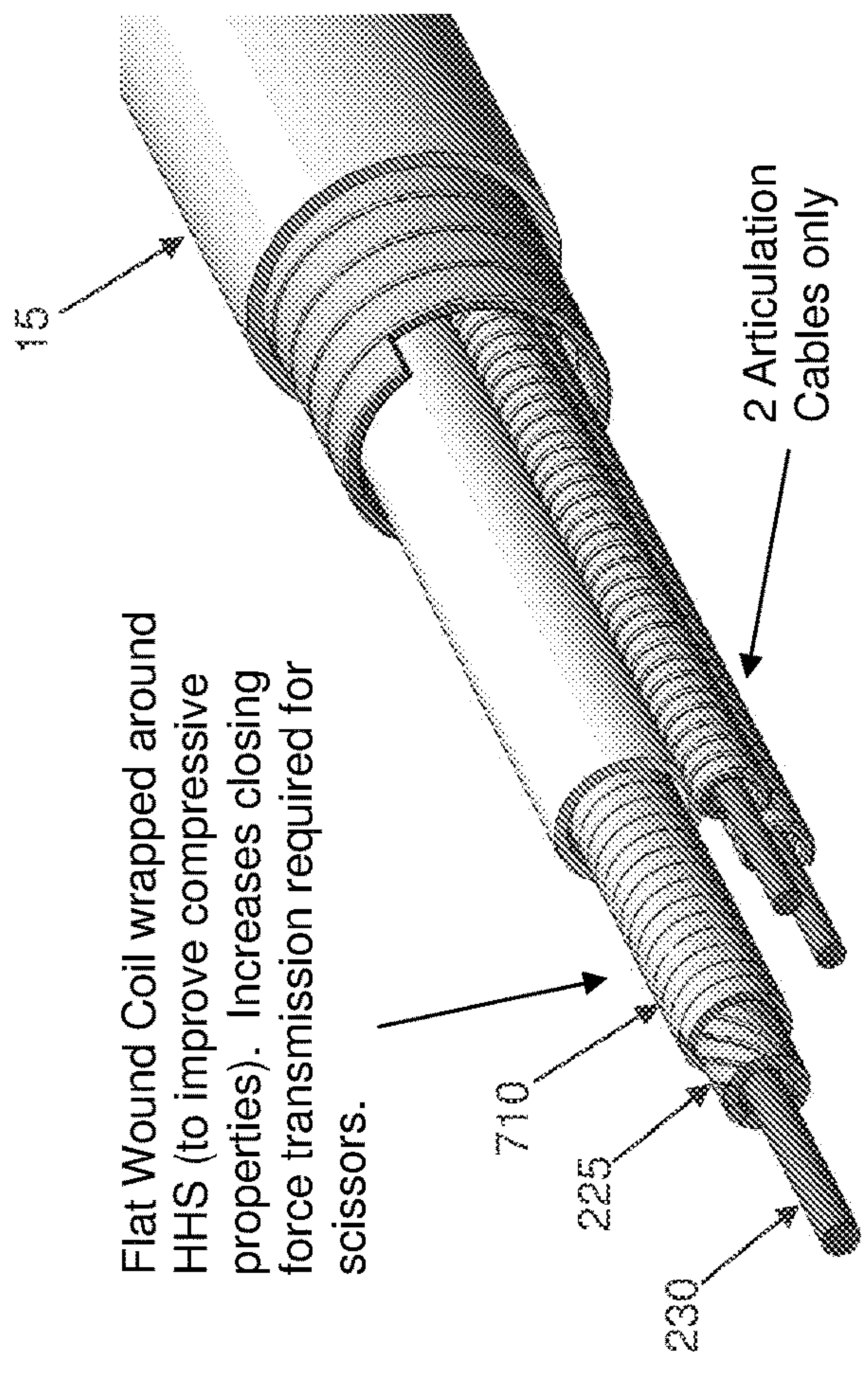


FIG. 70

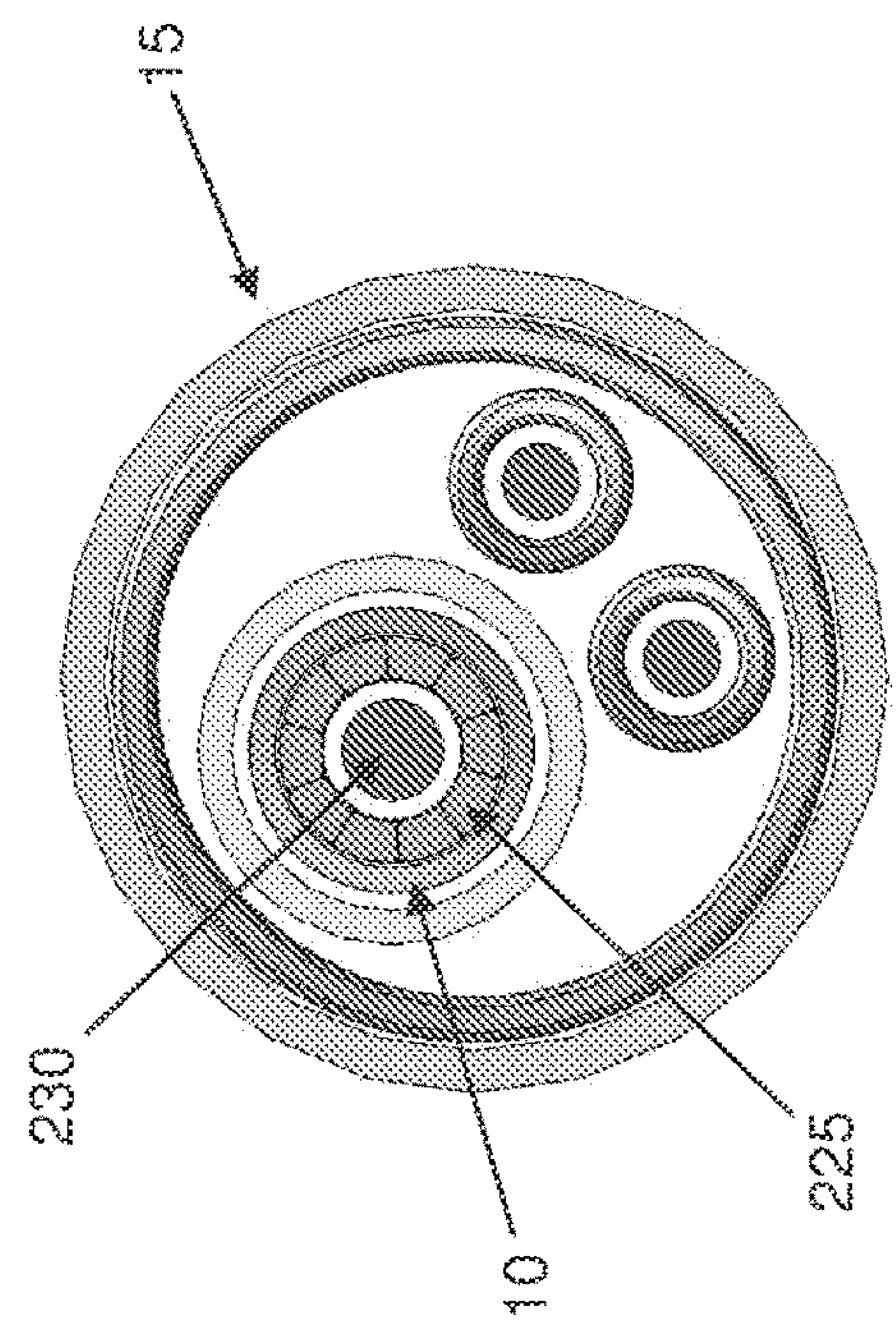


FIG. 71

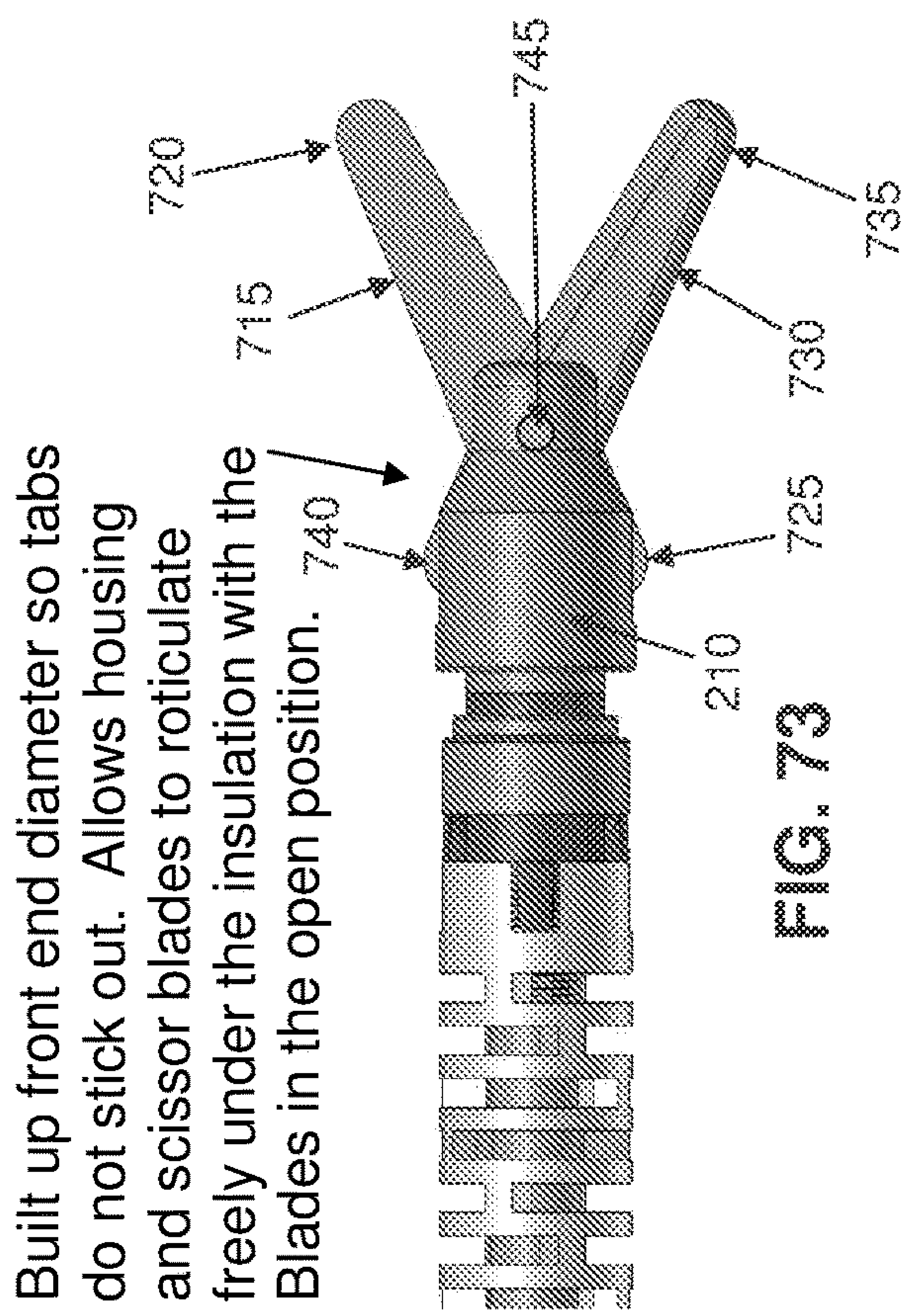

Built up front end diameter so tabs do not stick out. Allows housing and scissor blades to roticulate freely under the insulation with the Blades in the open position.
720
745
715
735
730
740
725
210

FIG. 73

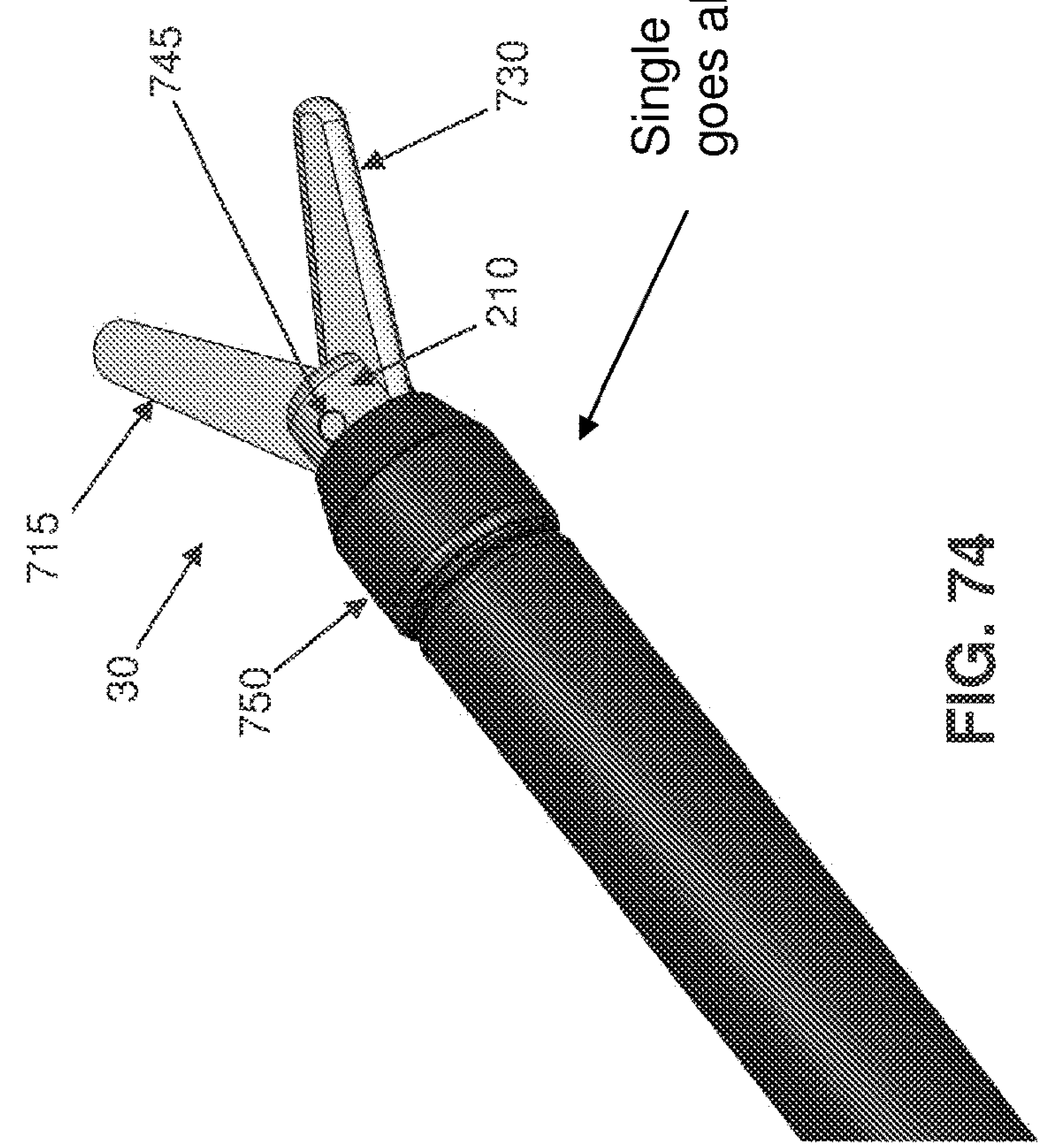

Single Piece Insulation (shrink tube) goes all the way to Housing Pivot
745
730
210
715
30
750

FIG. 74

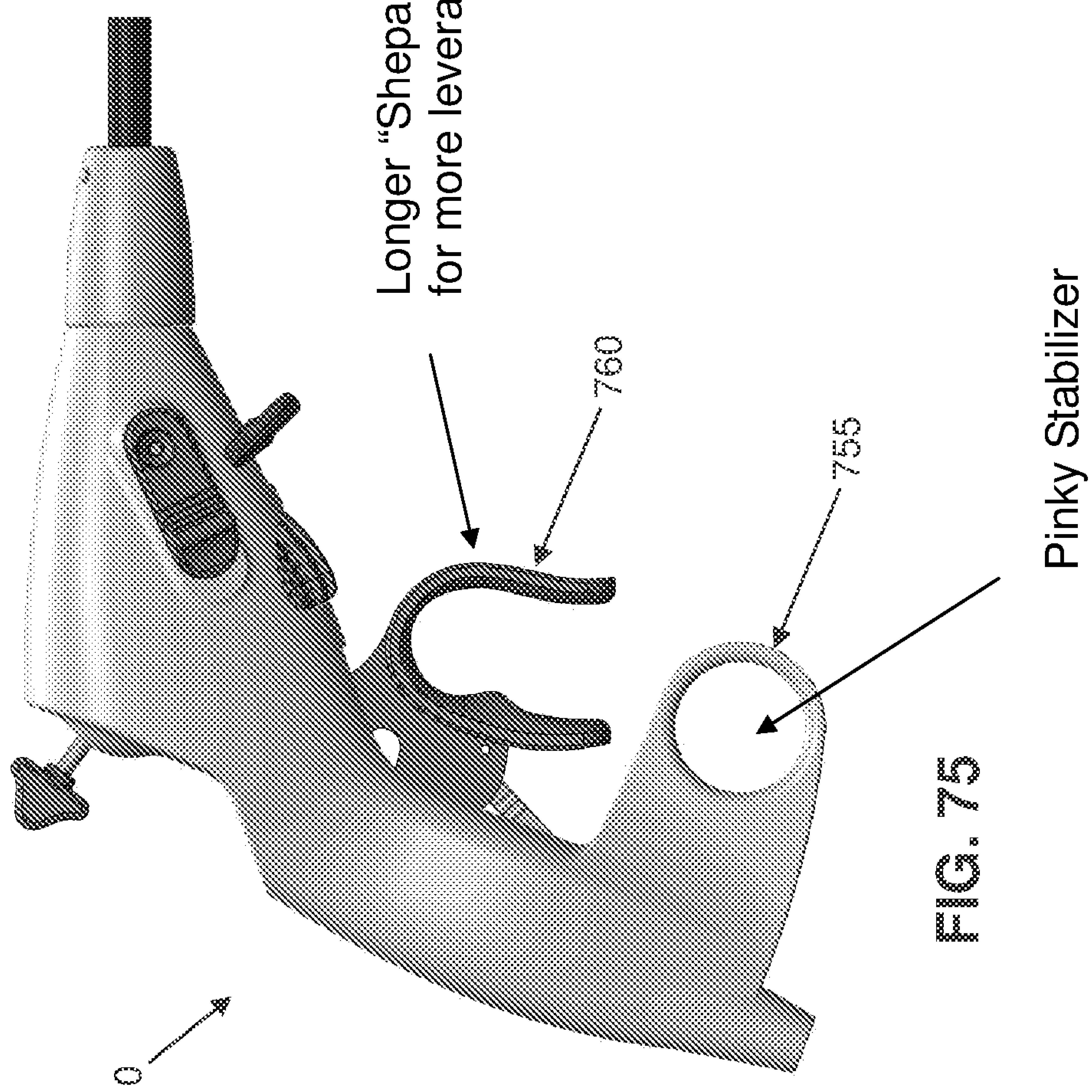

Longer "Shepard's Hook" trigger for more leverage
760
755
Pinky Stabilizer
10

FIG. 75

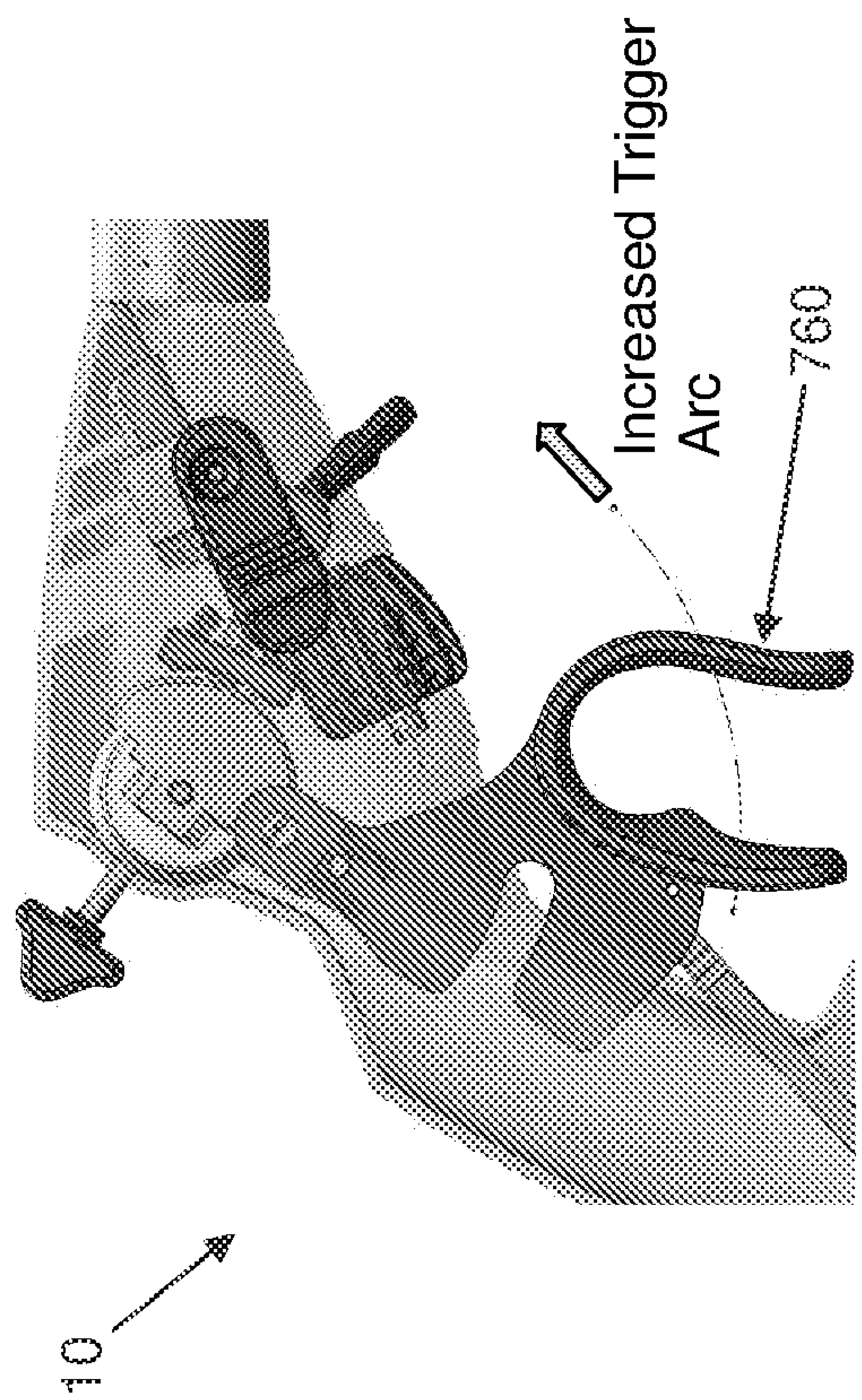

Increased Trigger Arc
760
10

FIG. 76

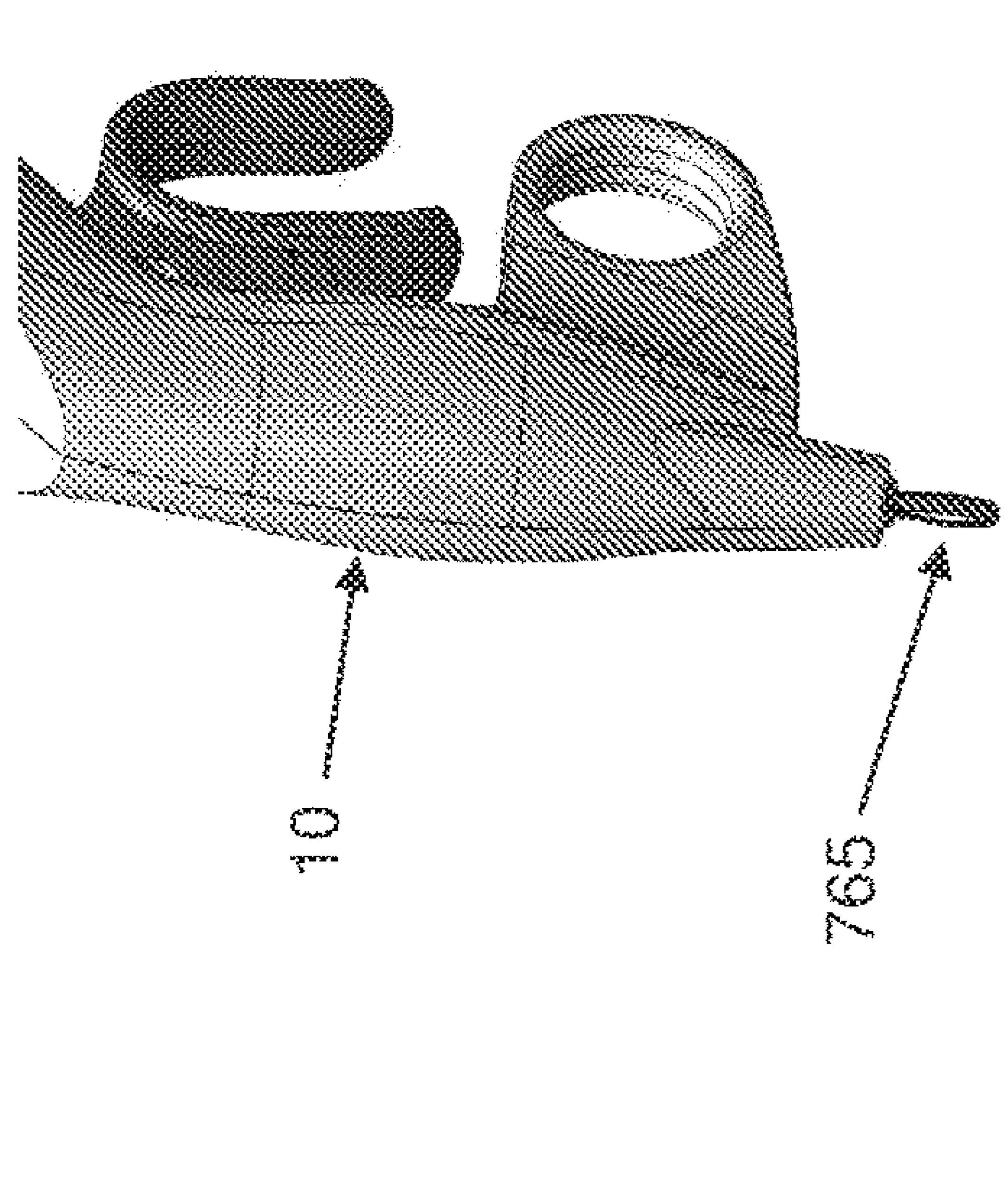


FIG. 77

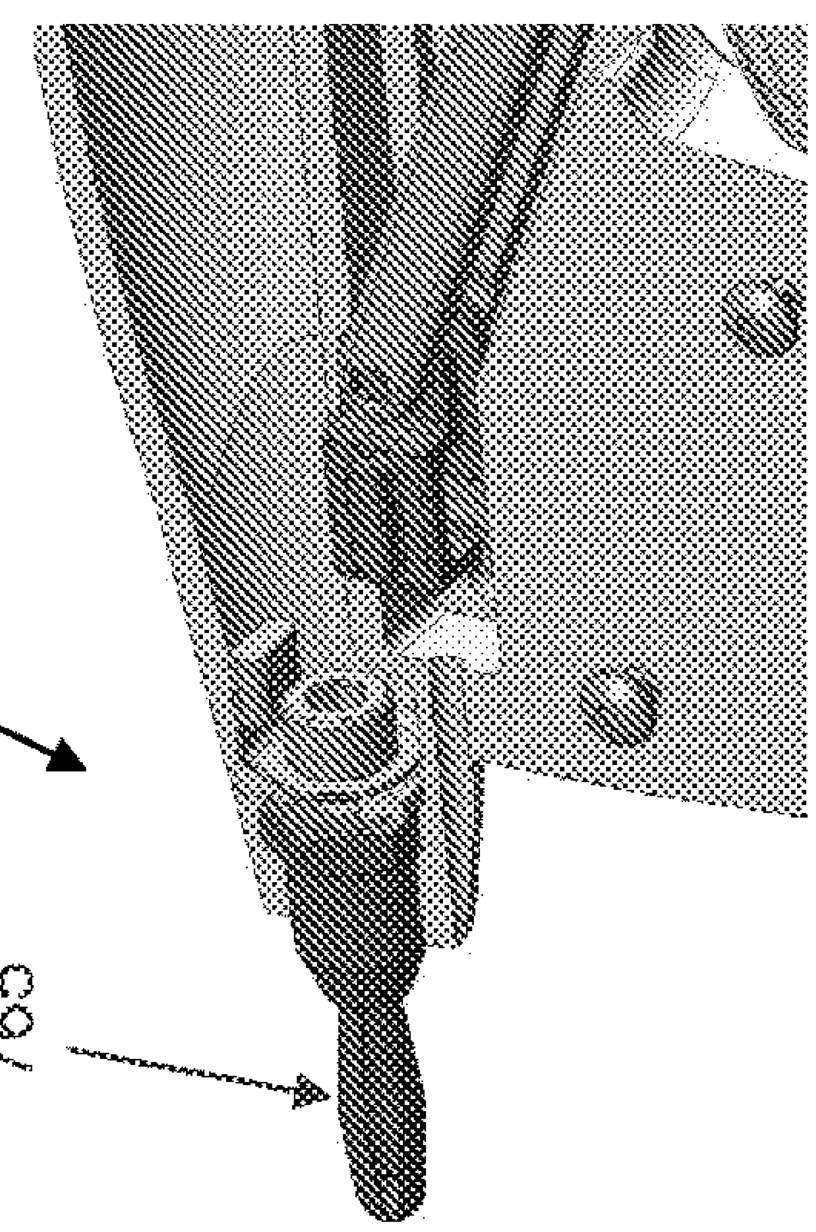


FIG. 78

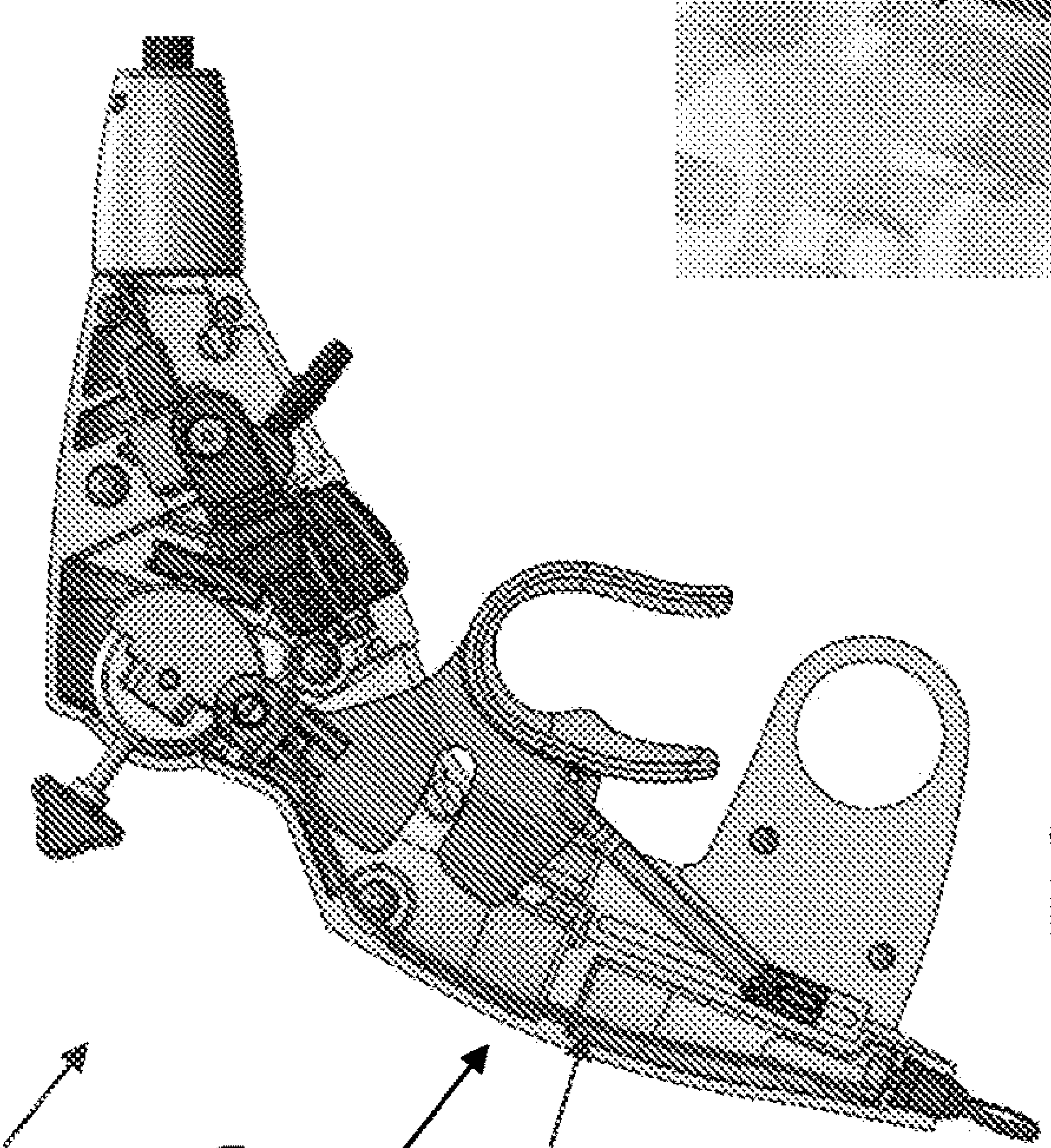


FIG. 79

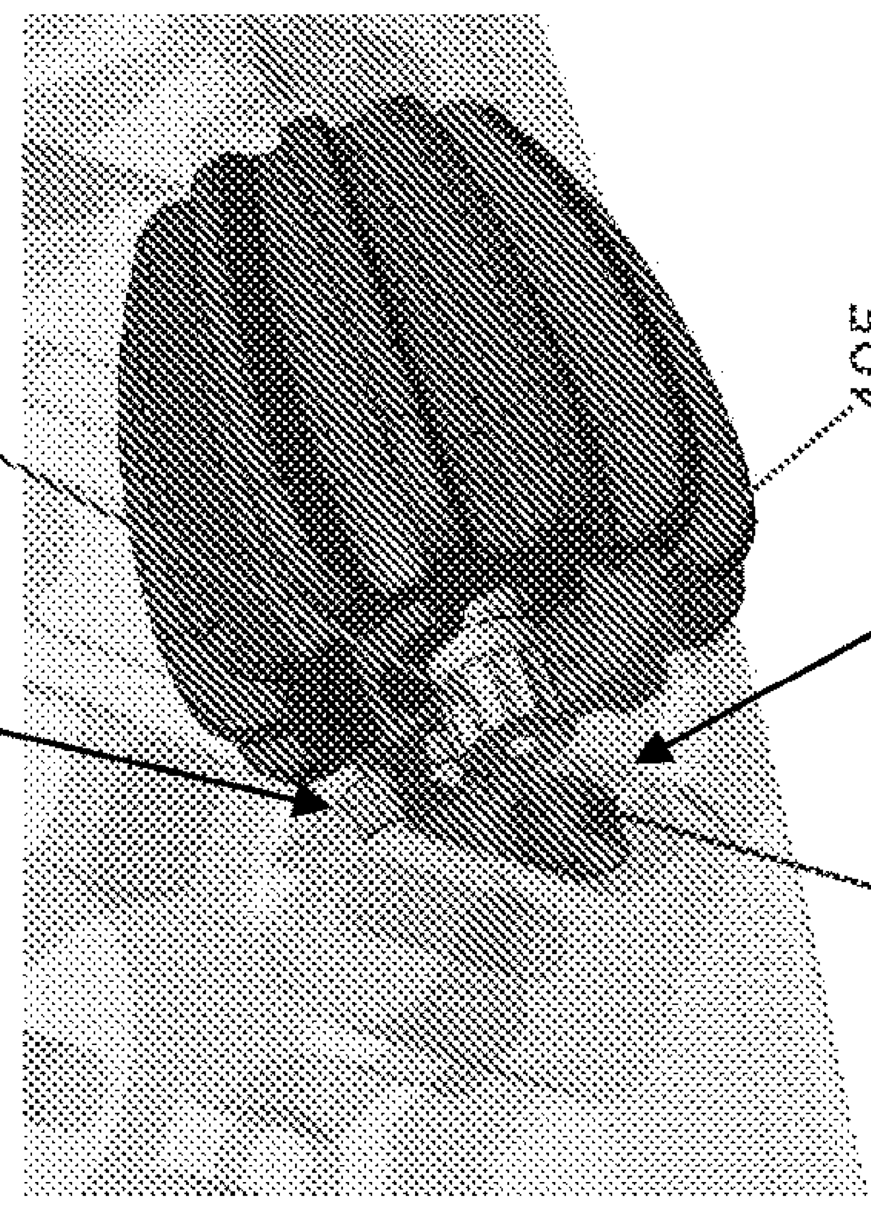


FIG. 80

MEDICAL INSTRUMENTS FOR PERFORMING MINIMALLY-INVASIVE PROCEDURES

REFERENCE TO PENDING PRIOR PATENT APPLICATIONS

This patent application is a continuation of U.S. patent application Ser. No. 15/298,605, filed Oct. 20, 2016 by Lumendi Ltd. for MEDICAL INSTRUMENTS FOR PERFORMING MINIMALLY-INVASIVE PROCEDURES, which patent application claims benefit of:

(i) prior U.S. Provisional Patent Application Ser. No. 62/244,026, filed Oct. 20, 2015 by Lumendi Ltd. and Jonathan O'Keefe et al. for MEDICAL INSTRUMENTS FOR PERFORMING MINIMALLY-INVASIVE PROCEDURES; and

(ii) prior U.S. Provisional Patent Application Ser. No. 62/400,759, filed Sep. 28, 2016 by Lumendi Ltd. and Jonathan O'Keefe et al. for MEDICAL INSTRUMENTS FOR PERFORMING MINIMALLY-INVASIVE PROCEDURES.

The three (3) above-identified patent applications are hereby incorporated herein by reference.

FIELD OF THE INVENTION

This invention relates to medical instruments in general, and more particularly to medical instruments for performing minimally-invasive procedures.

BACKGROUND OF THE INVENTION

Minimally-invasive medical procedures have become commonplace. In a typical minimally-invasive procedure, access to an internal site is effected through one or more small portals (e.g., a natural body orifice, a small incision in the skin, etc.). A scope (e.g., a colonoscope, an arthroscope, an endoscope, etc.) is inserted through a portal so as to provide visualization of the internal site, and then one or more medical instruments are inserted, either through the same portal (e.g., via an internal channel in the scope) or through another portal, so that the medical instruments can be used to carry out a procedure at the internal site under the visualization provided by the scope.

In many cases the internal site may be difficult to reach due to anatomical constraints, equipment limitations, etc. By way of example but not limitation, in many situations it may be desirable for a medical instrument to be advanced to the internal site through an internal channel of a scope, or for a medical instrument to be advanced to the internal site alongside the scope, and then bent (e.g., along a short radius) so as to enter the visual field of the scope, so that the desired procedure is carried out under the visualization provided by the scope. And in many cases, the path along which the medical instrument needs to be advanced may be tortuous (e.g., endoluminally within the colon). In this situation, it is necessary for the medical instrument to be highly flexible, capable of articulating with a range of different motions, and configured for precise control, while being operated (e.g., along a tortuous path) from only the handle end (i.e., the proximal end) of the medical instrument. In practice, this is extremely difficult to achieve.

The present invention is intended to provide a novel medical instrument capable of such function.

SUMMARY OF THE INVENTION

The present invention comprises a novel medical instrument for performing minimally-invasive procedures. The novel medical instrument is highly flexible, capable of articulating with a range of different motions, and configured for precise control, while being operated (e.g., along a tortuous path) from only the handle end of the medical instrument.

The novel medical instrument generally comprises a handle and a shaft extending distally from the handle. The shaft generally comprises an elongated, flexible proximal portion and a distal articulating portion which is mounted to the distal end of the flexible proximal portion. An end effector is mounted to the distal end of the distal articulating portion. The end effector may take many different forms (e.g., graspers, injection needles, scissors, hot snares, monopolar probes, hemostasis clips, bipolar forceps, suction tubes, single-fire or multi-fire closure devices such as staplers and tackers, dissector forceps, retrieval baskets, monopolar scissors, etc.). For clarity of illustration, the end effector is shown in the figures as a grasper. The handle may take any one of many different forms (e.g., a pistol grip, a shaft grip, etc.). For clarity of illustration, the handle is shown in the figures as a pistol grip.

In accordance with the present invention, the flexible proximal portion of the shaft is configured to be a highly flexible element capable of extending a significant length (e.g., 95 cm-140 cm) along a tortuous path, the distal articulating portion of the shaft is configured to be capable of universal articulation relative to the distal end of the flexible proximal portion of the shaft, and the end effector is configured to be selectively rotated relative to the distal end of the distal articulating portion and may be selectively actuated, with all functions able to be carried out by a single hand of a user via the handle. In one preferred form of the invention, substantially the entire shaft of the medical instrument is flexible, with the portion of the shaft proximal to a transition point (i.e., the flexible proximal portion) being passively flexible (e.g., able to follow a tortuous path), and the portion of the shaft distal to the transition point (i.e., the distal articulating portion) being actively flexible (e.g., able to be universally articulated to a desired configuration).

As will hereinafter be described in further detail, the novel medical instrument is capable of at least the following motions:

Motion 1—longitudinal movement of the end effector by longitudinal movement of the handle (sometimes hereinafter referred to as a "longitudinal motion function");

Motion 2—rotational movement of the end effector by rotational movement of the handle (sometimes hereinafter referred to as a "torquing motion function");

Motion 3—articulating movement of the end effector relative to the handle by articulating the distal articulating portion of the shaft relative to the distal end of the flexible proximal portion of the shaft (sometimes hereinafter referred to as a "universal articulation function");

Motion 4—rotational movement of the end effector relative to the distal end of the distal articulating portion of the shaft by rotating the end effector relative to the shaft (sometimes hereinafter referred to as a "roticulation function"); and

Motion 5—actuation of the end effector, e.g., selectively moving elements of the end effector relative to one another so as to carry out a medical procedure, e.g., opening and closing the jaws of a grasper-type end effector (sometimes hereinafter referred to as a "jaw open/close function").

In one preferred form of the present invention, there is provided apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, each of the plurality of articulation cables having an articulation cable housing disposed about the articulation cable such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends, with the articulation cable housings providing a counterforce to the flexible spine;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated.

In another preferred form of the present invention, there is provided a method for performing a minimally-invasive procedure, the method comprising:

obtaining apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, each of the plurality of articulation cables having an articulation cable housing disposed about the articulation cable such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends, with the articulation cable housings providing a counterforce to the flexible spine;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

using the apparatus to perform a minimally-invasive procedure.

In another preferred form of the present invention, there is provided apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates, wherein the rotatable element comprises a hollow tubular structure extending distally from the handle, the hollow tubular structure being formed out of a plurality of filars which are wound and swaged together, and further wherein the rotatable element further comprises a laser-cut hypotube secured to the hollow tubular structure, such that when the hollow tubular structure is rotated, the laser-cut hypotube is also rotated; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated.

In another preferred form of the present invention, there is provided a method for performing a minimally-invasive procedure, the method comprising:

obtaining apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates, wherein the rotatable element comprises a hollow tubular structure extending distally from the handle, the hollow tubular structure being formed out of a plurality of filars which are wound and swaged together, and further wherein the rotatable element further comprises a laser-cut hypotube secured to the hollow tubular structure, such that when the hollow tubular structure is rotated, the laser-cut hypotube is also rotated; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

using the apparatus to perform a minimally-invasive procedure.

In another preferred form of the present invention, there is provided apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates;

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

wherein the flexible portion of the shaft comprises an outer coil secured to the flexible spine, a rigid tube configured to rotate relative to the handle, and an outer covering secured to the rigid tube and the flexible spine, such that rotation of the rigid tube causes rotation of the outer covering which causes rotation of the flexible spine.

In another preferred form of the present invention, there is provided a method for performing a minimally-invasive procedure, the method comprising:

obtaining apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates;

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

wherein the flexible portion of the shaft comprises an outer coil secured to the flexible spine, a rigid tube configured to rotate relative to the handle, and an outer covering secured to the rigid tube and the flexible spine, such that rotation of the rigid tube causes rotation of the outer covering which causes rotation of the flexible spine; and

using the apparatus to perform a minimally-invasive procedure.

In another preferred form of the present invention, there is provided apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates;

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

wherein the proximal end of the shaft further comprises a rigid portion, and wherein the apparatus further comprises a tool support mounted to a patient support, the tool support comprising an opening for receiving the rigid portion.

In another preferred form of the present invention, there is provided a method for performing a minimally-invasive procedure, the method comprising:

obtaining apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates;

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

wherein the proximal end of the shaft further comprises a rigid portion, and wherein the apparatus further comprises a tool support mounted to a patient support, the tool support comprising an opening for receiving the rigid portion; and

using the apparatus to perform a minimally-invasive procedure.

In another preferred form of the present invention, there is provided apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated;

the shaft being configured such that when the articulating portion has been articulated, rotation of the rotatable element occurs without the build-up of spring energy within the shaft.

In another preferred form of the present invention, there is provided a method for performing a minimally-invasive procedure, the method comprising:

obtaining apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated;

the shaft being configured such that when the articulating portion has been articulated, rotation of the rotatable element occurs without the build-up of spring energy within the shaft; and

using the apparatus to perform a minimally-invasive procedure.

In another preferred form of the present invention, there is provided apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated.

In another preferred form of the present invention, there is provided a method for performing a minimally-invasive procedure, the method comprising:

obtaining apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

using the apparatus to perform a minimally-invasive procedure.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will be more fully disclosed or rendered obvious by the following detailed description of the preferred embodiments of the invention, which is to be considered together with the accompanying drawings wherein like numbers refer to like parts, and further wherein:

FIG. **1** is a schematic view showing a novel medical instrument formed in accordance with the present invention;

FIG. **1**A is a schematic view showing the handle and proximal end of the shaft of the novel medical instrument shown in FIG. **1**;

FIG. **1**B is a schematic view showing the distal end of the shaft and the end effector of the novel medical instrument shown in FIG. **1**;

FIGS. **2-23** are schematic views showing further details of the shaft and the end effector of the novel medical instrument shown in FIG. **1**;

FIGS. **24-46**B are schematic views showing further details of the handle and the proximal end of the shaft of the novel medical instrument shown in FIG. **1**;

FIGS. **47-55** are schematic views showing a novel tool support which may be used in conjunction with the novel medical instrument shown in FIG. **1**;

FIGS. **56-58**F are schematic views showing another novel medical instrument formed in accordance with the present invention;

FIGS. **59-62** are schematic views showing another form of end effector for the novel medical instrument of the present invention;

FIGS. **63-66** are schematic views showing another novel medical instrument formed in accordance with the present invention;

FIGS. **67-72** are schematic views showing another novel medical instrument formed in accordance with the present invention;

FIGS. **73** and **74** are schematic views showing another novel medical instrument formed in accordance with the present invention;

FIGS. **75** and **76** are schematic views showing another novel medical instrument formed in accordance with the present invention; and

FIGS. **77-80** are schematic views showing another novel medical instrument formed in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

1 the Novel Medical Instrument in General

The present invention comprises a novel medical instrument for performing minimally-invasive procedures. The novel medical instrument is highly flexible, capable of articulating with a range of different motions, and configured for precise control, while being operated (e.g., along a tortuous path) from only the handle end of the medical instrument.

Looking first at FIGS. **1**, **1**A, **1**B and **2**, there is shown a novel medical instrument **5** formed in accordance with the present invention. Novel medical instrument **5** generally comprises a handle **10** and a shaft **15** extending distally from handle **10**. Shaft **15** generally comprises an elongated, flexible proximal portion **20** and a distal articulating portion **25** which is mounted to the distal end of flexible proximal portion **20**. An end effector **30** is mounted to the distal end of distal articulating portion **25**. End effector **30** may take many different forms (e.g., graspers, injection needles, scissors, hot snares, monopolar probes, hemostasis clips, bipolar forceps, suction tubes, single-fire or multi-fire closure devices such as staplers and tackers, dissector forceps, retrieval baskets, monopolar scissors, etc.). For clarity of illustration, end effector **30** is shown in the figures as a grasper. Handle **10** may take any one of many different forms (e.g., a pistol grip, a shaft grip, etc.). For clarity of illustration, handle **10** is shown in the figures as a pistol grip.

In accordance with the present invention, flexible proximal portion **20** of shaft **15** is configured to be a highly flexible element capable of extending a significant length (e.g., 95 cm-140 cm) along a tortuous path, distal articulating portion **25** of shaft **15** is configured to be capable of universal articulation relative to the distal end of flexible proximal portion **20** of shaft **15**, and end effector **30** is configured to be selectively rotated relative to the distal end of distal articulating portion **25** and may be selectively actuated, with all functions able to be carried out by a single hand of a user via handle **10**. In one preferred form of the invention, substantially the entire shaft **15** of medical instrument **5** is flexible, with the portion of shaft **15** proximal to a transition point **32** (i.e., flexible proximal portion **20**) being passively flexible (e.g., able to follow a tortuous path), and the portion of shaft **15** distal to transition point **32** (i.e., distal articulating portion **25**) being actively flexible (e.g., able to be universally articulated to a desired configuration).

As will hereinafter be described in further detail, novel medical instrument is capable of at least the following motions:

Motion 1—longitudinal movement of end effector **30** by longitudinal movement of handle **10** (sometimes referred to herein as a "longitudinal motion function");

Motion 2—rotational movement of end effector **30** by rotational movement of handle **10** (sometimes referred to herein as a "torquing motion function");

Motion 3—articulating movement of end effector **30** relative to handle **10** by articulating distal articulating portion **25** of shaft **15** relative to the distal end of flexible proximal portion **20** of shaft **15** (sometimes referred to herein as a "universal articulation function");

Motion 4—rotational movement of end effector **30** relative to the distal end of distal articulating portion **25** of shaft **15** by rotating end effector **30** relative to shaft **15** (sometimes referred to herein as a "roticulation function"); and

Motion 5—actuation of end effector **30**, e.g., selectively moving elements of end effector **30** relative to one another so as to carry out a medical procedure, e.g., opening and closing the jaws of a grasper-type end effector (sometimes referred to herein as a "jaw open/close function").

2 Construction of Shaft **15**

2.1 Flexible Proximal Portion **20**

Looking now at FIGS. **1**, **1**A, **1**B and **2-4**, flexible proximal portion **20** of shaft **15** generally comprises an elongated flexible outer coil **35** (FIGS. **2** and **3**) having a distal end **40**, a proximal end **45** and a lumen **50** extending therebetween. Distal articulating portion **25** of shaft **15** is mounted to distal end **40** of outer coil via intervening elements (see below). Proximal end **45** of outer coil **35** is secured to a shaft adapter **55** which is, in turn, secured to handle **10** (see below).

Means for selectively articulating distal articulating portion **25** relative to the distal end of flexible proximal portion **20** (i.e., relative to distal end **40** of outer coil **35**), means for selectively rotating end effector **30** relative to distal articulating portion **25**, and means for selectively actuating end effector **30** extend through lumen **50** of outer coil **35**, as will hereinafter be discussed in further detail.

In one preferred form of the invention, a rigid tube **60** (FIGS. **1**A and **4**) is provided at the proximal end of flexible proximal portion **20** (i.e., disposed about the proximal end **45** of outer coil **35** and secured to shaft adapter **55**), whereby to provide a region of increased rigidity for mounting novel medical instrument **5** to a tool support (e.g., a table-mounted tool support) as will hereinafter be discussed in further detail. If desired, rigid tube **60** may comprise a fillet **65** (FIG. **4**) at the distal end of rigid tube **60** which provides a smooth transition between the outer surface of rigid tube **60** and the outer surface of the portion of flexible proximal portion **20** located distal to rigid tube **60**.

2.2 Distal Articulating Portion **25** in General

As discussed above, distal articulating portion **25** is configured to selectively articulate relative to the distal end of flexible proximal portion **20**. To this end, and looking now at FIGS. **2** and **5**, distal articulating portion **25** generally comprises a distal articulation link assembly **70**, a proximal articulation link assembly **75** and a flex spine **80** extending between distal articulation link assembly **70** and proximal articulation link assembly **75**. Proximal articulation link assembly **75** is configured to be mounted to the distal end of flexible proximal portion **20** of shaft **15** and to provide a counterforce surface to enable selective articulation of distal articulation link assembly **70** and flex spine **80**, as will hereinafter be discussed in further detail.

2.2.1 Proximal Articulation Link Assembly **75**

Looking now at FIGS. **2** and **6**, proximal articulation link assembly **75** is disposed at the distal end **40** of outer coil **35** of flexible proximal portion **20**. The distal end of proximal articulation link assembly **75** provides a counterforce surface to enable selective flexing of distal articulation link assembly **70** and flex spine **80** relative to the distal end of flexible proximal portion **20** of shaft **15** (i.e., in order to effect universal articulation of distal articulating portion **25**).

More particularly, proximal articulation link assembly **75** (FIG. **6**) comprises a body **85** having a pair of distally-extending fingers **90** which are configured to engage flex spine **80** (FIG. **5**) as will hereinafter be discussed in further detail. A plurality of bores **95** (FIG. **6**), disposed about a central bore **100** (FIG. **18**), are formed in body **85** and sized to receive a plurality of articulation cables (see below). If desired, bores **95** may comprise counterbores (not shown) disposed at their proximal ends for receiving articulation cable housings as will hereinafter be discussed. Central bore **100** (FIG. **18**) may comprise a counterbore **102** (FIGS. **6** and **18**) disposed at its distal end for facilitating mounting of distal articulating link assembly **70** to body **85**, as will hereinafter be discussed.

Body **85** of proximal articulation link assembly **75** bears against a plurality of articulation cable housings **235** (see below) which, in turn, bear against handle in order for proximal articulation link assembly **75** to provide a counterforce surface for selective flexing of distal articulating portion **25** of shaft **15**, as will hereinafter be discussed. Note that outer coil **35** is secured to body **85** of proximal articulation link assembly **75**, but provides substantially no counterforce to body **85**—the counterforce to body **85** is provided by the articulation cable housings.

2.2.2 Distal Articulation Link Assembly **70**

Looking now at FIGS. **2**, **5** and **7**, distal articulation link assembly **70** generally comprises a body **105** (FIG. **7**) having a central opening **110** passing therethrough, and a short laser-cut hypotube **115** extending proximally therefrom. Short laser-cut hypotube **115** comprises a distal end **120**, a proximal end **125** and a lumen **130** extending therebetween. Short laser-cut hypotube **115** is configured to be highly flexible, but with sufficient column strength, so as to permit selective articulation of body **105** relative to proximal articulation link assembly **75** when proximal end **125** of short laser-cut hypotube **115** bears against body **85** (FIG. **6**) of proximal articulation link assembly **75** and an off-center proximal force is applied to body **105**, as will hereinafter be discussed. Proximal end **125** of short laser-cut hypotube **115** is mounted to body **85** of proximal articulation link assembly **75** (e.g., via welding). Distal end **120** of short laser-cut hypotube **115** is mounted to body **105** (e.g., via welding), with lumen **130** of short laser-cut hypotube **115** being aligned with central opening **110** of body **105** when distal articulation link assembly **70** is in its relaxed (i.e., unbiased) condition. As a result of this construction, rotation of body **85** of proximal articulation link assembly **75** causes rotation of laser-cut hypotube **115**, whereby to cause rotation of body **105** of distal articulation link assembly **70**. Body **105** also comprises a pair of distal seats **135** (only one of which is shown in FIG. **7**) for mounting one or more articulation cables to body **105**, as will hereinafter be discussed in further detail. Body **105** also comprises two proximally-extending fingers **137** for mating with flex spine **80** (FIG. **5**), as will hereinafter be discussed in further detail.

2.2.3 Flex Spine **80**

Looking now at FIG. **5**, flex spine **80** generally comprises a flexible body **140** having a distal end **141** and a proximal end **142**. A plurality of axially-aligned openings **145**, and a central bore **150**, extend between distal end **141** and proximal end **142**. Openings **145** are sized to each receive an articulation cable therein as will hereinafter be discussed. Central bore **150** is sized to receive short laser-cut hypotube **115** (FIG. **7**) of distal articulation link assembly **70**. Proximal end **142** of flex spine **80** comprises proximal seats **155** for seating the aforementioned distally-extending fingers **90** (FIG. **6**) of proximal articulation link assembly **75**, and distal end **141** of flex spine **80** comprises distal seats **160** for receiving the aforementioned proximally-extending fingers **137** (FIG. **7**) of distal articulation link assembly **70**. It will be appreciated that when flex spine **80** is mounted in this fashion, flex spine **80** is fixed against rotation relative to either distal articulation link assembly **70** or proximal articulation link assembly **75**.

2.2.4 Rotatable Housing Assembly **165**

Looking next at FIGS. **5** and **8-12**, the distal end of distal articulating portion **25** comprises a rotatable housing assembly **165** (FIG. **9**) for rotatably mounting end effector **30** to distal articulation link assembly **70**, as will hereinafter be discussed.

More particularly, rotatable housing assembly **165** generally comprises a collar **170**, a long laser-cut hypotube **180** having a distal end **185**, a proximal end **190** and a lumen **195** extending therebetween. Rotatable housing assembly **165** also comprises a rotation connector **200** (FIGS. **9** and **10**) having an opening **205** formed therein which is fixedly mounted to distal end **185** of long laser-cut hypotube **180** such that lumen **195** of long laser-cut hypotube **180** is aligned with opening **205** of rotation connector **200** when rotatable housing assembly **165** is in its relaxed (i.e., unbiased) condition, and such that long laser-cut hypotube **180** and rotation connector **200** can rotate as a unit. An end effector mount **210** (FIGS. **8**, **9**, **11** and **12**), is mounted to rotation connector **200** such that end effector mount **210** rotates when rotation connector **200** rotates (i.e., when long laser-cut hypotube **180** rotates). End effector **30** is mounted to end effector mount **210** (see below). Rotation connector **200** and end effector mount **210** are rotatably mounted to body **105** of distal articulation link assembly **70** (FIGS. **5** and **7**) via collar **170** (FIG. **5**). More particularly, rotation connector **200** (FIG. **9**) is rotatably mounted to collar **170** and is able to rotate relative to collar **170**. End effector mount **210** is mounted to rotation connector **200** and engages a distal shoulder **215** (FIG. **10**) of rotation connector **200**. Collar **170** is fixedly mounted to body **105** of distal articulation link assembly **75** (FIG. **7**). Thus, end effector mount **210** (FIG. **9**) is fixedly mounted to rotation connector **200** which is in turn fixedly connected to long laser-cut hypotube **180**, and the foregoing subassembly (end effector mount **170**, rotation connector **200** and long laser-cut hypotube **180**) is rotatably mounted to collar **170**, with collar **170** being fixedly mounted to distal articulation link assembly **70** (FIG. **5**), and with long laser-cut hypotube **180** extending through central bore **150** of flex spine **80** and through bore **100** (FIG. **18**) of body **85** of proximal articulating link assembly **75**.

2.3 End Effector **30**

End effector **30** may take many different forms (e.g., graspers, injection needles, scissors, hot snares, monopolar probes, hemostasis clips, bipolar forceps, suction tubes, single-fire or multi-fire closure devices such as staplers and tackers, dissector forceps, retrieval baskets, monopolar scissors, etc.). For clarity of illustration, end effector **30** is shown in the figures as a grasper.

In one preferred form of the invention, and looking now at FIG. **8**, end effector **30** is mounted to end effector mount **210**. More particularly, in one preferred form of the invention, end effector **30** comprises a grasper having two opposed jaws **216**, **217** which are pivotally mounted to end effector mount **210** via a pin **217**A which passes through holes **217**B in jaws **216**, **217** and through holes **217**C in end effector mount **210**. A clevis **218** is mounted to jaws **216**, **217** via a pin **218**A disposed in slots **218**B formed in the proximal portions of jaws **216**, **217** such that reciprocal movement of a pull wire mounted to clevis **218** (see below) causes the opposing jaws **216**, **217** of the grasper to open and close relative to one another, as will hereinafter be discussed.

2.4 Articulation Means in General

As discussed above, shaft **15** also comprises (i) means for selectively articulating distal articulating portion **25** (FIG. **2**) relative to flexible proximal portion **20**, (ii) means for selectively rotating rotatable housing assembly **165** (FIG. **9**) relative to shaft **15**, and hence for selectively rotating end effector **30** relative to shaft **15**, and (iii) means for selectively actuating end effector **30** (FIG. **8**). All of the foregoing means are actuated via handle **10**, as will hereinafter be discussed.

More particularly, and looking now at FIGS. **13** and **14**, shaft **15** generally comprises (i) four articulation cables **220** for selectively articulating distal articulating portion **25** relative to the distal end of flexible proximal portion **20**, (ii) an HHS coil **225** (e.g., a hollow helical strand of the sort sold by Fort Wayne Metals of Fort Wayne, Ind.) for selectively rotating rotatable housing assembly **165** (FIG. **9**) relative to shaft **15**, and hence for selectively rotating end effector **30** relative to shaft **15**, and (iii) a pull wire **230** for selectively actuating end effector **30**.

2.4.1 Articulation Cables **220**

Looking next at FIGS. **13-16**, in a preferred form of the invention, four articulation cables **220** run from handle **10** to distal seats **135** (FIGS. **15** and **16**) of distal articulation link assembly **70**, with articulation cables **220** extending through bores **95** of body **85** (FIG. **6**), through openings **145** of flex spine **80** (FIG. **5**) to distal seats **135** of body **105** (FIG. **16**). Articulation cables **220** are preferably each slidably disposed within an articulation cable housing **235** (FIG. **13**). The distal ends **240** of articulation cable housings **235** are mounted to body **85** (FIG. **15**) of proximal articulation link assembly **75** (i.e., via thread adjusters **330**, as will hereinafter be discussed). Articulation cable housings **235** bear against body **85** of proximal articulation link assembly **75** and provide a counterforce to body **85** for articulation of distal articulating portion **25** of shaft **15** relative to flexible proximal portion **25** of shaft **15**. Articulation cable housings **235** also separate articulation cables **220** from one another and from HHS coil **225**, and help ensure smooth sliding movement of articulation cables **220** within flexible proximal portion **20** of shaft **15** (i.e., over the distance between handle **10** and proximal articulation link assembly **75**, which may be substantial in length (e.g., 95 cm-140 cm) and follow a tortuous path when medical instrument **5** is disposed in a patient). If desired, in order to facilitate mounting the distal ends of articulation cable housings **235** to the body **85** (FIG. **15**), the proximal end of each bore **95** may comprise a counterbore (not shown) sized to receive the distal end **240** of a given articulation cable housing **235**.

Looking now at FIGS. **15** and **16**, after articulation cables **220** pass distally through openings **145** (FIG. **5**) in flex spine **80**, articulation cables **220** are attached (e.g., via welding, crimping, etc.) to distal seats **135** of body **105** of distal articulation link assembly **70**. By way of example but not limitation, two of the articulation cables **220** may be provided by a single length of cable, with that single length of cable having a tube **245** (FIG. **16**) crimped thereto and with tube **245** being welded (or otherwise affixed) to a distal seat **135**.

As a result of this construction, by selectively pulling proximally on a proximal end of an articulation cable **220**, body **105** (FIG. **7**) of distal articulation link assembly **70** can be articulated laterally, whereby to articulate distal articulating portion **25** of shaft **15**. Furthermore, by providing at least three articulation cables **220**, with the three or more articulation cables being positioned about the perimeter of body **105**, substantially universal articulation of distal articulation link assembly **70** can be achieved, whereby to provide substantially universal articulation for distal articulating portion **25** of shaft **15**.

2.4.2 HHS Coil **225**

Looking next at FIGS. **13**, **14** and **17**, HHS coil **225** comprises a distal end **250** (FIG. **17**), a proximal end **255** (FIG. **26**) and a lumen **260** (FIG. **13**) extending therebetween. In order to facilitate rotation of HHS coil **225** within shaft **15**, HHS coil **225** is preferably disposed within a flexible, friction-reducing sleeve **267** (FIG. **13**). More particularly, HHS coil **225** preferably comprises a plurality of filars which are wound and swaged together so as to together form a hollow tubular structure. By way of example but not limitation, HHS coil **225** may comprise a hollow helical strand of the sort sold by Fort Wayne Metals of Fort Wayne, Ind. In one preferred form of the present invention, HHS coil **225** comprises 10 filars which are wound and swaged together into a singular flexible structure. Distal end **250** (FIG. **17**) of HHS coil **225** is mounted to long laser-cut hypotube **180** (FIG. **17**) of rotatable housing assembly **165** (FIG. **9**) via a sleeve (or crimp) **265** (FIG. **17**), such that long laser-cut hypotube **180** (and hence end effector mount **210** carrying end effector **30**) rotate when HHS coil **225** rotates. It will be appreciated that, as a result of this construction, the rotational disposition of end effector **30** can be adjusted by selectively rotating HHS coil **225**, whereby to rotate long laser-cut hypotube **180** and hence end effector mount **210**, to which end effector **30** is secured. Significantly, by using HHS coil **225** and long laser-cut hypotube **180** to transmit torque down shaft **15**, any build-up of torquing spring energy within the shaft is minimized, even when shaft **15** follows a tortuous path and distal articulating portion **25** has been articulated relative to the longitudinal axis of shaft **15**.

2.4.3 Pull Wire **230**

Looking next at FIGS. **13**, **14**, **18** and **19**, pull wire **230** is provided for selectively actuating end effector **30**. The distal end of pull wire **230** (FIG. **19**) is secured to clevis **218** of end effector **30**, with clevis **218** being slidably mounted to jaws **216**, **217** of end effector **30**, and with jaws **216**, **217** being pinned to end effector mount **210**, such that reciprocal movement of pull wire **230** causes the opposing jaws **216**, **217** of end effector **30** to open and close relative to one another.

2.5 Further Details on the Construction of Shaft **15**

When shaft **15** is fully assembled, and looking now at FIGS. **18-23**, body **85** (FIG. **18**) of proximal articulation link assembly **75** (FIG. **6**) is mounted to distal end **40** (FIG. **2**) of flexible outer coil **35**, with distal ends **240** (FIG. **15**) of articulation cable housings **235** being mounted to body **85** of proximal articulation link assembly **75**, and with articulation cables **220** passing through bores **95** (FIG. **6**) formed in body **85**. Distal articulation link assembly **70** (FIG. **7**) is mounted to proximal articulation link assembly **75** by mounting proximal end **125** of short laser-cut hypotube **115** in counterbore **102** (FIG. **6**) of body **85**. Flexible body **140** (FIG. **5**) of flex spine **80** is "sandwiched" between body **105** (FIG. **7**) of distal articulation link assembly **70** and body **85** (FIG. **6**) of proximal link assembly **75**, with distally-extending fingers **90** of body **85** being disposed in proximal seats **155** (FIG. **5**) of flex spine **80** and with proximally-extending fingers **137** of body **105** being disposed in distal seats **160** of flex spine **80**. Short laser-cut hypotube **115** (FIG. **7**) of distal articulation link assembly **70** passes through central bore **150** (FIG. **5**) of flexible body **140** of flex spine **80**. When articulation cables **220** are pulled proximally, the distal end of short laser-cut hypotube **115** bears against body **85** of proximal articulation link assembly **75** (which, in turn, bears against articulation cable housings **235**), whereby to selectively articulate distal articulating portion **25** of shaft **15**.

Long laser-cut hypotube **180** (FIGS. **9**, **10** and **17**) of rotatable housing assembly **165** extends proximally through short laser-cut hypotube **115** (FIG. **18**) such that the proximal end **190** (FIG. **17**) of long laser-cut hypotube **180** passes through body **85** of proximal articulation link assembly **75** (i.e., by passing through counterbore **102** and central bore **100** of body **85**) and is secured to HHS coil **225** (FIG. **17**), e.g., via sleeve **265**. Collar **170** (FIG. **18**) of rotatable housing assembly **165** (FIG. **9**) is mounted to body **105** of distal articulation link assembly **70** and covers distal seats **135** (and the portions of articulation cables **220** mounted thereto). Rotation connector **200** (FIGS. **9** and **10**) is mounted to the distal end of long laser-cut hypotube **180**. Rotation connector **200** is also mounted to end effector mount **210**. End effector **30** is mounted to end effector mount **210**. As a result of this construction, when HHS coil **225** is rotated, long laser-cut hypotube **180** is rotated and rotation connector **200** is rotated and end effector mount **210** is rotated, whereby to cause rotation of end effector **30**.

Pull wire **230** (FIG. **18**) extends distally through lumen **260** of HHS coil **225** (FIGS. **13** and **14**) and distally through lumen **195** (FIG. **9**) of long laser-cut hypotube **180**, exiting rotation connector **200**. The distal end of pull wire **230** is connected to end effector **30**. As a result of this construction, reciprocal movement of a pull wire **230** causes the opposing jaws **216**, **217** (FIG. **8**) of the grasper to open and close relative to one another.

Flexible proximal portion **20** of shaft **15** is preferably covered with a protective sleeve or outer covering (e.g., Pebax®) **270** (FIGS. **18**, **20** and **21**), with the proximal end of protective sleeve or outer covering **270** being secured (e.g., bonded) to rigid tube **60** and with the distal end of protective sleeve or outer covering **270** being secured (e.g., bonded) to body **85** of proximal articulation link assembly **75**, and distal articulating portion **25** of shaft **15** is preferably covered with a protective sleeve or outer covering **275** (FIGS. **18** and **22**), with the proximal end of protective sleeve or outer covering **275** being secured to body **85** of proximal articulation link assembly **75** and with the distal end of protective sleeve or outer covering **275** extending up to and over the proximal portion of end effector **30**, whereby to protect shaft **15** and permit easy insertion of shaft **15** into the body of a patient via a natural body orifice, a cannula, the lumen of another surgical instrument, etc.

The proximal end of shaft **15** is mounted to handle **10** (FIG. **1**) such that articulation cables **220**, HHS coil **225** and pull wire **230** may be selectively actuated using handle **10**, as will hereinafter be discussed in further detail.

3 Handle **10** in General

Looking now at FIGS. **24-26**, handle **10** generally comprises an internal cavity **280**, an articulation control assembly **285** for selectively moving articulation cables **220** (and hence selectively articulating distal articulating portion **25** of shaft **15**), a push rod lock assembly **290** for selectively locking articulation control assembly **285** in a desired position (and hence locking distal articulating portion **25** of shaft **15** in a selected position), a roticulation control assembly **295** for selectively rotating HHS coil **225** (and hence selectively rotating end effector **30**), and a trigger assembly **300** for selectively actuating pull wire **230** (and hence selectively actuating end effector **30**).

3.1 Articulation Control Assembly **285**

Looking now at FIGS. **27-36**, articulation control assembly **285** generally comprises a ball plate **305** (FIG. **28**) fixedly mounted within internal cavity **280** of handle **10**, a thumbstick ball assembly **310** configured to be selectively pivoted relative to ball plate **305**, and a thumbstick **315** configured to be engaged by the thumb of a user.

Ball plate **305** comprises a plurality of threaded openings **320** (FIG. **28**) and a center opening **325** for receiving pushrod lock assembly **290**, as will hereinafter be discussed in further detail. Threaded openings **320** are configured to receive a plurality of threaded adjusters **330** (FIGS. **29** and **30**) which are, in turn, mounted to the proximal ends (FIGS. **21** and **30**) of each articulation cable housing **235**. It will be appreciated that, as a result of this construction, the proximal ends of articulation cable housings **235** bear against ball plate **305** (which is, in turn, fixedly mounted to handle **10**), such that articulation cable housings **235** can provide a counterforce to body **85** of proximal articulation link assembly **75** when articulation cables **220** are pulled proximally. Each threaded adjuster **330** comprises a central lumen passing therethrough, such that an articulation cable **220** (FIG. **30**) may pass through the threaded adjuster (and hence, through threaded openings **320** of ball plate **305**) to be mounted to thumbstick ball assembly **310**, as will hereinafter be discussed. An enlargement **335** (FIG. **30**) is formed on (or attached to) the proximal end of each articulation cable **220**, whereby to facilitate mounting articulation cables **220** to thumbstick ball assembly **310**. Ball plate **305** also comprises a proximally-facing concave recess **340** (FIG. **29**) for providing clearance to thumbstick ball assembly **310** which is pivotally seated within a seat **342** disposed within internal cavity **280** of handle **10**, as will hereinafter be discussed in further detail.

Thumbstick ball assembly **310** comprises a hemispherical distal ball **345** (FIG. **32**) and a hemispherical proximal ball **350**. Hemispherical distal ball **345** preferably has a maximum diameter (i.e., the diameter at its proximal end) which is greater than the maximum diameter of hemispherical distal ball **345** (i.e., the diameter at its distal end), whereby to provide a proximal circumferential seat **355** (FIG. **31**) about the proximal end of hemispherical distal ball **345**. A plurality of openings (or grooves) **360** (FIG. **31**) are formed in the proximal circumferential seat **355** for receiving articulation cables **220** when enlargements **335** are seated on proximal circumferential seat **355**, as will hereinafter be discussed. As a result of this construction, when the rounded distal end of hemispherical distal ball **345** is pivotally disposed within seat **342** in internal cavity **280** of handle **10** (FIG. **27**) and spaced from ball plate **305** (FIG. **33**), articulation cables **220** may be passed through openings (or grooves) **360** in proximal circumferential seat **355** as enlargements **335** seat on proximal circumferential seat **355**. Hence, articulation cables **220** may be selectively moved by selectively pivoting hemispherical distal ball **345** within its seat **342** inside internal cavity **280** of handle **10** (i.e., by selectively pivoting thumbstick **315**, as will hereinafter be discussed in further detail).

Thumbstick **315** comprises a threaded stem **362** (FIG. **33**) and a thumb seat **363**. The distal end of threaded stem **362** secures hemispherical proximal ball **350** to hemispherical distal ball **345**. Thumb seat **363** is secured to the proximal end of threaded stem **362**. As a result of this construction, thumbstick **315** can be used to selectively move hemispherical distal ball **345**, whereby to selectively move articulation cables **220**, whereby to selectively articulate distal articulating portion **25** of shaft **15** relative to flexible proximal portion **20** of shaft **15**.

3.1.1 Push Rod Lock Assembly **290**

Looking next at FIGS. **27**, **28** and **33-36**, pushrod lock assembly **290** generally comprises an actuation lever **365** (FIG. **33**), a cam **370** mounted to actuation lever **365**, and a pushrod lock assembly plate **375** having a pushrod **380** mounted thereto and extending proximally therefrom. Pushrod **380** is preferably disposed within a sleeve **385**. In one preferred form of the invention, a spring **390** (FIG. **35**) is disposed over sleeve **385** so as to bias pushrod lock assembly plate **375** distally away from ball plate **305** (FIG. **36**). Pushrod **380** is slidably disposed in center opening **325** (FIG. **28**) of ball plate **305** and extends proximally therefrom toward thumbstick ball assembly **310** (FIG. **33**). Actuation lever **365** and cam **370** are rotatably mounted within cavity **280** of handle **10**, with cam **370** contacting pushrod lock assembly plate **375** such that movement of actuation lever **365** cams pushrod lock assembly plate **375** (and hence pushrod **380**) proximally against the power of spring **390**, whereby to cause the free end of pushrod **380** to engage hemispherical distal ball **345**, thereby locking thumbstick ball assembly **310** against movement. When actuation lever **365** is moved in a second, opposite direction, cam **370** is moved so as to allow pushrod lock assembly plate **375** (and hence pushrod **380**) to move distally under the power of spring **390**, away from hemispherical distal ball **345**, whereby to allow free movement of thumbstick ball assembly **310**. As a result, it will be appreciated that pushrod lock assembly **290** can be used to selectively lock thumbstick ball assembly **310** in a desired position, whereby to selectively lock distal articulating portion **25** of shaft **15** in a desired (e.g., articulated) configuration.

3.2 Roticulation Control Assembly **295**

Looking next at FIGS. **37-41**, roticulation control assembly **295** generally comprises a roticulation knob **395** (FIGS. **37** and **38**) having a keyway **400** (FIG. **38**) passing therethrough, and a roticulation key **405**. Roticulation key **405** comprises a distal end **406**, a proximal end **407** and a lumen **408** extending therebetween. HHS coil **225** is received within lumen **408** of roticulation key **405** and is secured to roticulation key **405** such that rotation of roticulation key **405** effects rotation of HHS coil **225**. As noted above, HHS coil **225** is secured to long laser-cut hypotube **180**, and long laser-cut hypotube **180** is secured to end effector mount **210**, such that rotation of HHS coil **225** causes rotation of long laser-cut hypotube **180** which causes rotation of end effector mount **210** (and hence rotation of end effector **30**). Distal end **406** of rotaticulation key **405** is received in keyway **400** of roticulation knob **395** such that roticulation key **405** is engaged by roticulation knob **395** and rotates when roticulation knob **395** rotates. As a result of this construction, rotation of roticulation knob **395** causes rotation of roticulation key **405** which causes rotation of HHS coil **225** and hence rotation of end effector **30**. In a preferred form of the invention, keyway **400** of roticulation knob **395** comprises a non-circular cross-sectional profile which matches the non-circular cross-sectional profile of distal end **406** of roticulation key **405**.

Roticulation knob **395** is rotatably mounted within cavity **280** of handle **10** such that a portion of roticulation knob **395** protrudes out of handle **10** (FIG. **37**), whereby to permit roticulation knob **395** to be selectively rotated by a user. Pull wire **230** (FIG. **40**), which is disposed within HHS coil **225**, extends through roticulation key **405** and is selectively actuated using trigger assembly **300** (FIG. **25**), as will hereinafter be discussed.

Proximal end **407** of roticulation key **405** extends out of roticulation knob **395** (FIG. **39**). In one preferred form of the present invention, proximal end **407** (FIG. **38**) of roticulation key **405** comprises a plurality of teeth **409** for releasably engaging a ball nose spring plunger **410** (FIG. **41**). Ball nose spring plunger **410** is mounted within cavity **280** of handle **10** such that ball nose spring plunger **410** releasably engages teeth **409** disposed on proximal end **407** of roticulation key **405**. By virtue of the engagement between ball nose spring plunger **410** and roticulation key **405**, roticulation key **405** (and hence HHS coil **225** which is mounted to roticulation key **405**) are prevented from "spontaneously" rotating absent deliberate rotation of roticulation knob **395**. Thus, ball nose spring plunger **410** prevents accumulated spring tension (e.g., spring tension which can build up when rotating HHS coil **225** using roticulation knob **395**) from "unraveling" HHS coil **225** and thereby causing unintentional rotation of HHS coil **225** (and hence unintentional rotation of end effector **30**).

3.3 Trigger Assembly **300**

Looking next at FIGS. **42-46**, **46**A, **46**B and **47**, trigger assembly **300** generally comprises a trigger **415** pivotally mounted to handle **10**, a sled **420** (FIG. **43**) movably disposed within cavity **280** of handle **10**, and one or more lever arms **425** which connect trigger **415** to sled **420** such that when trigger **415** is actuated (i.e., pulled), sled **420** moves proximally within cavity **280** of handle **10**, whereby to move pull wire **230** proximally, whereby to actuate end effector **30**, as will hereinafter be discussed in further detail.

More particularly, sled **420** comprises a cavity **430** (FIG. **45**), a distal bushing **435** (FIG. **46**) disposed within cavity **430**, a proximal bushing **440** disposed within cavity **430**, and a spring **445** disposed between distal bushing **435** and proximal bushing **440**. An inner support tube **450** is secured to pull wire **230** (e.g., by a crimp sleeve **451** disposed at the proximal end of inner support tube **450**). An outer support tube **452** is disposed over the distal portion of inner support tube **450**, with inner support tube **450** able to slide freely within outer support tube **452**. Outer support tube **452** also comprises an outer support tube collar **453** which is sized to be mounted within a seat **454** (FIG. **46**B) formed in internal cavity **280** of handle **10**. A spring **455** (FIG. **42**) is disposed in the proximal end of handle **10** so as to bias sled **420** distally.

As a result of this construction, when sled **420** is moved proximally (i.e., by pulling trigger **415**) against the power of spring **455** (FIG. **42**), distal bushing **435** (FIG. **46**) moves proximally, bearing against spring **445** which, in turn, bears against proximal bushing **440**, which bears against crimp sleeve **451** and pulls pull wire **230** proximally. Thus, as sled **420** moves proximally, proximal bushing **440** and crimp sleeve **451** also move proximally, whereby to move pull wire **230** proximally and thereby actuate end effector **30**. It should be appreciated, however, that inasmuch as sled **420** is not mounted directly to pull wire **230**, proximal bushing **440** and spring **445** act as a force limiter, with spring **445** yielding when the force on pull wire **230** exceeds a given level, whereby to cease applying a proximal force to pull wire **230**. Put another way, if the force applied to move sled **420** proximally exceeds the force biasing proximal bushing **440** away from distal bushing **435** (i.e., the biasing force provided by spring **445**), spring **445** will compress, thereby allowing proximal bushing **440** and crimp sleeve **451** (and hence inner support tube **450** and pull wire **230**) to remain stationary as sled **420** moves proximally. In this way trigger **415** can be pulled through a "full stroke" without the danger of breaking pull wire **230**. It should also be appreciated that since spring **455** biases sled **420** distally, and since crimp sleeve **451** is engaged by a shoulder **456** when sled **420** moves proximally, sled **420** will return to its distal position within handle **10** and pull wire **230** will be moved distally.

4 Exemplary Method of Use

In an exemplary use of novel medical instrument **5** in a minimally-invasive procedure, the profile of end effector **30** is reduced (e.g., where end effector **30** comprises a grasper, the jaws of the grasper are closed); shaft **15** is straightened; handle **10** is longitudinally advanced so as to longitudinally advance the distal end of medical instrument **5** through a portal and into the body (e.g., along a tortuous path); handle **10** is longitudinally advanced and/or rotated, and/or distal articulating portion **25** of shaft **15** is bent and/or end effector **30** is roticulated, so that end effector **30** appropriately addresses the target tissue at the internal site; end effector **30** is used to perform the desired procedure (e.g., where end effector **30** comprises a surgical grasper the jaws of the grasper are opened and closed to grasp tissue) at the internal site; and the distal end of medical instrument **5** is withdrawn from the body, e.g., handle **10** is longitudinally withdrawn through the portal (during which the handle may also be rotated, and/or distal articulating portion **25** of shaft **15** is unbent and/or the end effector roticulated as necessary), so that the end effector is withdrawn from the body.

It will be appreciated that novel medical instrument **5** is capable of at least the following motions:

Motion 1—longitudinal movement of end effector **30** by longitudinal movement of handle **10** (sometimes referred to herein as a "longitudinal motion function");

Motion 2—rotational movement of end effector **30** by rotational movement of handle **10** (sometimes referred to herein as a "torquing motion function");

Motion 3—articulating movement of end effector **30** relative to handle **10** by articulating distal articulating portion **25** of shaft **15** relative to the distal end of flexible proximal portion **20** of shaft **15** (sometimes referred to herein as a "universal articulation function");

Motion 4—rotational movement of end effector **30** relative to the distal end of distal articulating portion **25** of shaft **15** by rotating end effector **30** relative to shaft **15** (sometimes referred to herein as a "roticulation function"); and

Motion 5—actuation of end effector **30**, e.g., selectively moving elements of end effector **30** relative to one another so as to carry out a medical procedure, e.g., opening and closing the jaws of a grasper-type end effector (sometimes referred to herein as a "jaw open/close function").

It will be appreciated by those skilled in the art that, if desired, the medical instrument may be modified so as to provide less (or more) than the five aforementioned motions, e.g., the roticulation function may be eliminated, an additional rotational function such as selective rotation of shaft **15** may be added, etc.

5 Novel Tool Support

Looking next at FIGS. **47-49**, there is shown a novel tool support **460** which may be used to support medical instrument **5**. Tool support **460** generally comprises a clamp **465** for mounting tool support **460** to a surgical table **466**, an adjustable base **470** for mounting one or more medical instrument(s) **5** to tool support **460**, and an adjustable arm **475** (FIG. **48**) for adjustably mounting base **470** to clamp **465**. One or more instrument adapters **480** (FIG. **49**) are mounted to base **470**, whereby to permit mounting of one or more medical instrument(s) **5** to tool support **460** (i.e., by providing a support for handle **10** and/or rigid tube **60** at the proximal end of shaft **15**), as will hereinafter be discussed in further detail.

One or more tool channels **485**, configured for passing shaft **15** into a patient (or into the working lumen of another medical instrument), are mounted to the one or more instrument adapters **480**, as will hereinafter be discussed in further detail.

More particularly, and still looking at FIGS. **47-50**, clamp **465** is configured to be mounted to a stable object (e.g., to surgical table **466**) in order to permit a surgeon to manipulate tool support **460** (and hence the one or more medical instruments **5** mounted thereto) relative to the patient and/or relative to other surgical instruments, as will hereinafter be discussed.

Adjustable arm **475** preferably comprises one or more segments **490** (FIG. **49**) which are adjustably mounted to one another, and to clamp **465** and to base **470**, whereby to permit the surgeon to precisely adjust the disposition of base **470** relative to the patient (and/or relative to another surgical instrument).

Looking now at FIGS. **49** and **50**, instrument adapters **480** each comprise a mount **495** and a tube **500**. Mount **495** is pivotally mounted to base **470** (FIG. **49**). Tube **500** has a lumen **505** sized to receive the proximal end of shaft **15** of medical instrument **5** (i.e., rigid tube **60** located at the proximal end of shaft **15**). If desired, lumen **505** may comprise a septum **515** for fluidically sealing tube **500** (and hence fluidically sealing tool chamber **485**), and/or tube **500** may comprise an end cap **520** for fluidically sealing tube **500** (and hence, for fluidically sealing tool chamber **485**).

Looking now at FIGS. **51-55**, there are shown some exemplary configurations for tool support **460**. It should be appreciated that base **470** of tool support **460** may comprise a plurality of pivots and/or arms, may be shaped in the form of an arc, and/or may comprise other geometries, etc., in order to accommodate the needs and/or preferences of the surgeon.

6 Medical Instrument **5** with Rotatable Shaft **15**

As discussed above, novel medical instrument **5** comprises a shaft **15** having a flexible proximal portion **20**, a distal articulating portion **25** which can be selectively articulated relative to the distal end of flexible proximal portion **20**, and an end effector **30** which can be selectively rotated relative to the distal end of distal articulating portion **25**. With this construction, longitudinal movement of handle **10** can be used to move shaft **15** distally and proximally, whereby to move end effector **30** distally and proximally; rotational movement of handle **10** can be used to rotate shaft **15**, whereby to rotate end effector **30**; articulation control assembly **285** (FIG. **25**) can be used to articulate distal articulating portion **25** of shaft **15**, whereby to redirect end effector **30**; roticulation control assembly **295** (FIG. **25**) can be used to rotate end effector **30**; and trigger assembly **300** (FIG. **25**) can be used to actuate end effector **30**. With the foregoing construction, flexible proximal portion **20** rotates as a unit with handle **10**.

However, it has been recognized that it may be desirable to be able to rotate flexible proximal portion **20** of shaft **15** independently of handle **10**. To this end, and looking now at FIGS. **56-58**, a novel rotatable shaft adapter mechanism **525** may be provided between shaft **15** and handle **10**, whereby to allow shaft **15** (i.e., both flexible proximal portion **20** and distal articulating portion **25**) to be selectively rotated relative to handle **10**.

More particularly, rotatable shaft adapter mechanism **525** is mounted to the proximal end of shaft **15** (i.e., mounted to the proximal end of flexible proximal portion **20**) and connects shaft **15** to handle **10**. It should be appreciated that, in this form of the invention, rotatable shaft adapter mechanism **525** replaces the aforementioned shaft adapter **55** (where the aforementioned shaft adapter **55** was fixedly secured to handle **10** and fixedly secured to the proximal end of outer coil **35**, and where rigid tube **60** was fixedly secured to shaft adapter **55**). More particularly, in this form of the invention, shaft **15** is rotatably mounted to the distal end of handle **10** and selectively locked/unlocked from rotation via rotatable shaft adapter mechanism **525**, as will hereinafter be discussed in further detail.

Still looking now at FIGS. **56-58**, in this form of the invention, rigid tube **60** of shaft **15** comprises a flange **530** disposed around the proximalmost end of rigid tube **60**. Flange **530** is received within a corresponding groove **535** formed in the distal end of handle **10** (i.e., formed within cavity **280** of handle **10** near the distalmost end of handle **10**), whereby to rotatably mount rigid tube **60** of shaft **15** to handle **10**. In this form of the invention, the proximal end of outer coil **35** is fixedly secured to rigid tube **60** (and the distal end of outer coil **35** is secured to body **85** of proximal articulation link assembly **75**). The outer circumference of the distalmost end of handle **10** comprises a plurality of keyways **540** (FIG. **57**) which are sized to receive a plurality of projections **542** formed on rotatable shaft adapter mechanism **525**, as will hereinafter be discussed in further detail. Note that, if desired, the locations of keyways **540** and projections **542** may be reversed from the foregoing, i.e., keyways **540** may be formed on rotatable shaft adapter mechanism **525** and projections **542** may be formed on the distalmost end of handle **10**.

Rotatable shaft adapter mechanism **525** generally comprises a shaft rotation knob **545** having a lumen **550** extending therethrough. Lumen **550** comprises a distal end **555**, a proximal end **560** and an annular shoulder **565** disposed therebetween. A spring **570** is disposed within distal end **555** of lumen **550**, extending between annular shoulder **565** and the proximal end **575** of a retaining cap **580** (FIGS. **58**, **58**A, **58**B, **58**C and **58**D) which is mounted circumferentially about the outer perimeter of shaft **15**, whereby to bias shaft rotation knob **545** proximally, so that projections **542** of shaft adapter mechanism **525** are received within keyways **540** of handle **10**, whereby to lock shaft rotation knob **545** against rotation. More particularly, retaining cap **580** comprises a pair of flats **585** which key to corresponding flats **590** formed on the outer surface of rigid tube **60** of shaft **15**. One or more spring fingers **591** engage a groove **592** on the outer surface of rigid tube **60**, whereby to lock retaining cap **580** to rigid tube **60**. Retaining cap **580** also comprises a plurality of key features **593** sized to be received in corresponding keyways **594** of shaft rotation knob **545**. As a result of this construction, rotation knob **545** is able to slide longitudinally (distally or proximally) relative to rigid tube **60** of shaft **15**, however, rotation knob **545** is locked against rotation relative to rigid tube **60** (and hence, relative to shaft **15**). Therefore, rotation knob **545** can be moved longitudinally without causing longitudinal motion of rigid tube **60** and shaft **15**, but rotation of rotation knob **545** will be transferred to rigid tube **60** (and to shaft **15** as will hereinafter be discussed).

Shaft rotation knob **545** is connected to rigid tube **60** of shaft **15** (e.g., via projections, a friction fit, etc.) so that shaft rotation knob **545** is longitudinally movable relative to rigid tube **60** but rotationally fixed to rigid tube **60**.

In this form of the invention, the proximal end of protective sleeve or outer covering (e.g., Pebax®) **270** is secured (e.g., bonded) to rigid tube **60** and the distal end of protective sleeve or outer covering **270** is secured (e.g., bonded) to body **85** of proximal articulation link assembly **75**. Significantly, protective sleeve or outer covering **270** is capable of transmitting torque between rigid tube **60** and body **85** of proximal articulation link assembly **75**.

As a result of this construction, spring **570** normally biases shaft rotation knob **545** proximally, whereby to cause projections **542** to engage keyways **540** and lock shaft **15** against rotation relative to handle **10**. However, when shaft rotation knob **545** is moved distally, against the power of spring **570**, projections **542** disengage from keyways **540**, thereby allowing shaft rotation knob **545** to be selectively rotated relative to handle **10**, whereby to selectively rotate rigid tube **60** relative to handle **10**, whereby to selectively rotate protective sleeve or outer covering **270** relative to handle **10**, whereby to selectively rotate body **85** of proximal articulation link assembly **75**, whereby to selectively rotate distal articulating portion **25** of shaft **15** relative to handle **10**. When shaft **15** has been rotated to the desired position relative to handle **10**, shaft rotation knob **545** is released and shaft rotation knob **545** moves proximally under the power of spring **570** such that projections **542** re-engage keyways **540**, thereby locking shaft **15** against further rotation relative to handle **10**.

Thus it will be seen that in this form of the invention, rigid tube **60** is rotatable relative to handle **10** but longitudinally fixed relative to handle **10**; shaft rotation knob **545** is connected to rigid tube **60** such that shaft rotation knob **545** can be moved longitudinally relative to rigid tube **60** but not rotationally relative to rigid tube **60**, such that shaft rotation knob **545** can be selectively locked to, or unlocked from, handle **10** so as to permit shaft rotation knob **545** to selectively rotate rigid tube **60**; and protective sleeve or outer covering **270** transmits torque between rigid tube **60** and body **85** of proximal articulation link assembly **75**, such that rotation of rigid tube **60** causes rotation of body **85** of proximal articulation link assembly **75**, whereby to rotate distal articulating portion **25** of shaft **15** relative to handle **10**.

It will be appreciated that unlimited rotation of rigid tube **60** and shaft **15** will cause articulation cables **220** and articulation cable housings **235** to wind on themselves; therefore, in one preferred form of the present invention, means are provided for limiting rotation of rigid tube **60** and shaft **15**. More particularly, in one preferred form of the invention, and looking now at FIGS. **58**E and **58**F, rigid tube **60** of shaft **15** preferably comprises a groove **595** extending partially circumferentially about the outer surface of shaft **15**. Groove **595** is disposed just distal to the proximal end of shaft **15** and extends partially, but not entirely, around the circumference of shaft **15**. A corresponding boss **596** is formed on the distal end of handle **10** and received within groove **595**. As a result of this construction, shaft **15** can be rotated only until boss **596** reaches one end of groove **595**. In a preferred form of the present invention, groove **580** is sized so that shaft **15** can be rotated up to 350 degrees.

7 Additional Constructions

In the foregoing disclosure, there is described a novel medical instrument comprising a handle, an elongated flexible shaft and an end effector disposed at the distal end of the shaft configured for performing a medical procedure. It should be appreciated that medical instrument **5** may be modified in a variety of ways in order to support different types of end effectors, to facilitate single-handed use of medical instrument **5**, to enhance the functionality of medical instrument **5**, etc.

7.1 Alternative End Effector

As discussed above, in a preferred form of the present invention, end effector **30** comprises a surgical grasper having two opposed jaws **216**, **217** (FIG. **8**).

In another preferred form of the present invention, and looking now at FIGS. **59-62**, end effector **30** comprises scissors **600** having opposing blades **605**, **610**. Blades **605**, **610** comprise sharp edges that contact one another in order to facilitate cutting (e.g., of tissue, suture, etc.) when blades **605**, **610** are brought together (i.e., closed). In order to ensure clean cutting by blades **605**, **610**, it is desirable to maintain blades **605**, **610** in tight contact with one another as blades **605**, **610** are brought together (i.e., closed). To this end, a beveled washer **615** (FIGS. **61** and **62**) is disposed between one of the blades **605**, **610** and the inner wall of end effector mount **210**. Beveled washer **615** is preferably disposed over the pin **217**A which pivotally mounts blades **605**, **610** to end effector mount **210**. By mounting beveled washer **615** in this manner, blades **605**, **610** are kept in tight engagement as they are brought together (i.e., closed), whereby to facilitate clean cutting (e.g., of tissue, of suture, etc.).

7.2 Finger Slide for Single-Handed Shaft Rotation

As discussed above, in one form of the present invention, shaft **15** is rotatably mounted to the distal end of handle **10** and can be selectively rotated using rotatable shaft adapter mechanism **525** (FIGS. **56-58** and **58**A-**58**F). With this form of the invention, the proximal end of shaft **15** is rotationally mounted to the distal end of handle **10** (e.g., by means of the aforementioned flange **530** (FIG. **58**) on rigid tube **60** being rotationally received within the aforementioned corresponding groove **535** formed in the distal end of handle **10**), and rotatable shaft adapter mechanism **525** is moved distally (i.e., pushed distally by the user against the power of spring **570**) in order to "unlock" shaft **15** (i.e., to allow shaft rotation knob **545**, and hence shaft **15**, to rotate). A user can then rotate shaft **15** as desired (i.e., by rotating rotatable shaft adapter mechanism **525**, and hence rotating shaft **15**). After the user has rotated shaft **15** as desired, shaft adapter mechanism **525** is released and automatically moves proximally (i.e., under the power of spring **570**) so as to "lock" shaft **15** against further rotation. This action typically requires that the user use one hand to push rotatable shaft adapter mechanism **525** distally (and thereafter rotate shaft **15**) while the user uses their other hand to keep handle **10** stationary.

However, it should be appreciated that it may also be desirable for a user to rotate shaft **15** using a single hand. To this end, in another form of the present invention, shaft **15** is kept stationary (e.g., via friction between the outer surface of shaft **15** and the interior of a tool channel (e.g., tool channel **485** (FIG. **48**), the lumen of a tool channel provided in another medical instrument such as an endoscope, etc.), handle **10** is selectively rotationally de-coupled from shaft **15**, and handle **10** is selectively rotated by a user to a desired rotational position using a single hand. Handle **10** is then rotationally re-coupled to shaft **15** and then rotated by the user (whereby to also rotate shaft **15**).

More particularly, with this form of the invention, and looking now at FIGS. **63-66**, a shaft rotation finger slide assembly **625** is provided in order to enable single-handed rotation of shaft **15**, as will hereinafter be discussed in further detail. Shaft rotation finger slide assembly **625** generally comprises a finger slide mechanism **630** which is slidably disposed within handle **10**, and a shaft collar **635** which is fixedly mounted to the proximal end of shaft **15** (e.g., fixedly mounted to rigid tube **60**).

Finger slide mechanism **630** comprises a saddle **640** having a pair of projections **645** extending through corresponding slots (not shown) formed in the side wall of handle **10**. A pair of finger slides **647** are secured to projections **645**. A post **650** extends distally from saddle **640** and is configured to selectively lock shaft collar **635** against rotation, as will hereinafter be discussed in further detail. A spring **655** biases saddle **640** (and hence post **650**) distally, such that post **650** engages shaft collar **635** when finger slide mechanism **630** is in its resting state, as will hereinafter be discussed in further detail.

Shaft collar **635** is fixedly mounted to the proximal end of shaft **15** (e.g., to rigid tube **60**). Shaft collar **635** comprises a distal end **660**, a proximal end **665** and a lumen **670** extending therebetween. A plurality of teeth **675** are disposed about the inside perimeter of lumen **670** at proximal end **665** of shaft collar **635**, with teeth **675** being spaced such that post **650** of finger slide mechanism **630** can be received within the gap between a pair of adjacent teeth **675**, whereby to lock shaft collar **635** (and hence shaft **15**) against rotation, as will hereinafter be discussed in further detail.

When a user desires to rotate shaft **15**, the user moves finger slides **647** proximally, whereby to move projections **645** proximally, whereby to move saddle **640** proximally against the power of spring **655**. As this occurs, post **650** is also moved proximally, whereby to disengage post **650** from teeth **675** of shaft collar **635** (and thereby rotationally de-couple handle **10** from shaft **15**). While holding projections **645** proximally, the user can then rotate handle **10** as desired relative to shaft **15**. Shaft **15** does not rotate as handle **10** is rotated (i.e., shaft **15** is maintained stationary by virtue of friction between the outer surface of shaft **15** and the interior of the lumen that shaft **15** is disposed in, e.g., tool channel **485**). After the user has rotated handle **10** to the desired degree, the user releases finger slides **647**, which allows projections **645** and saddle **640** (and hence post **650**) to move distally under the power of spring **655**, with post **650** moving distally into a space between a pair of teeth **675** of shaft collar **635**, whereby to rotationally re-couple handle **10** to shaft collar **635** (and hence shaft **15**). At this point, the user can rotate handle **10** as desired in order to rotate shaft **15**. By way of example but not limitation, if a user desires to rotate shaft **15** clockwise 90 degrees, the user can rotationally de-couple shaft **15** from handle **10** in the manner discussed above, rotate handle **10** counterclockwise 90 degrees (e.g., rotate the grip of handle **10** from the "6 o'clock" position to the "3 o'clock" position), re-couple shaft **15** to handle **10** in the manner discussed above, and then rotate handle **10** (and hence shaft **15**) clockwise 90 degrees (e.g., rotate the grip of handle **10** from the "3 o'clock" position to the "6 o'clock" position).

7.3 Single-Plane Articulation Mechanism

As discussed above, in one preferred form of the present invention, articulation control assembly **285** comprises thumbstick ball assembly **310**, which is configured to selectively pull one or more of four articulation cables **220** proximally, whereby to allow selective universal articulation of distal articulating portion **25** of shaft **15** relative to flexible proximal portion **20** of shaft **15** via movement of thumbstick ball assembly **310**.

However, it has been recognized that it is also sometimes desirable to provide a simplified articulation control assembly which may be used with only two articulation cables, e.g., to provide single-plane articulation of distal articulating portion **25** of shaft **15** relative to flexible proximal portion **20** of shaft **15**. To that end, in one form of the present invention, and looking now at FIGS. **67-69**, there is shown an articulation control assembly **680** which is similar to the articulation control assembly **285** discussed above, but which is configured to provide single-plane articulation, as will hereinafter be discussed in further detail.

More particularly, articulation control assembly **680** comprises a rocker **685** pivotally mounted within internal cavity **280** of handle **10**. Rocker **685** may be pivotally mounted within internal cavity **280** via an appropriately-formed seat disposed within internal cavity **280** of handle **10** or by other means (e.g., a pivot pin). A thumb lever **690** is mounted to rocker **685** and extends proximally through a slot **695** formed in the housing of handle **10** (FIG. **69**). A wedge-shaped thumb rest **700** is preferably mounted to the free end of thumb lever **690**. two articulation cables **220** (not shown) are mounted to rocker **685** (e.g., by mounting the proximal ends of articulation cables **220** within diametrically-opposed slots **705** formed on rocker **685**).

As a result of this construction, a user can selectively articulate, in a single plane, distal articulating portion **25** of shaft **15** by selectively moving thumb lever **690**, whereby to selectively pivot rocker **685** in a single plane, and thereby selectively pull one of the two articulation cables **220** which are mounted to rocker **685** proximally.

7.4 HHS Coil Comprising Compressive Outer Wrap

As discussed above, pull wire **230** is disposed within lumen **260** of HHS coil **225** and is able to slide freely relative to HHS coil **225** in order to selectively actuate end effector **30** (i.e., when a user pulls trigger **415** of handle **10**, whereby to move pull wire **230** proximally).

It has been found that inasmuch as shaft **15** (and hence, HHS coil **225**) can extend a substantial distance along a tortuous path (e.g., though the colon of a patient), HHS coil **225** can sometimes longitudinally compress (i.e., longitudinally shorten) while pull wire **230** does not longitudinally compress (i.e., longitudinally shorten). When this occurs, since HHS coil **225** provides the counterforce for pull wire **230**, pull wire **230** needs to be moved a further distance proximally in order to actuate end effector **30**. However, further proximal movement of pull wire **230** may not be possible if trigger **415** has reached the end of its "throw" (i.e., if trigger **415** cannot be pulled further).

In order to minimize longitudinal compression of HHS coil **225**, and looking now at FIGS. **70-72**, in one form of the present invention there is provided a flat wound coil **710** which is wound around HHS coil **225**. Flat wound coil **710** is welded to distal end **250** of HHS coil **225** and is welded to proximal end **255** of HHS coil **225**. Coil **710** rotates with HHS coil **225** and provides support to HHS coil **225**, whereby to minimize longitudinal compression of HHS coil **225**. As a result of this construction, HHS coil **225** does not compress longitudinally (i.e., HHS coil **225** does not shorten) when shaft **15** is disposed along a tortuous path.

7.5 Cover for End Effector Mount **210**

As discussed above, end effector **30** may be pivotally mounted within end effector mount **210** via a pin **217**A passing through the end effector and jaws **216**, **217** of the grasper.

However, with certain end effectors, it is necessary to provide openings in the sides of end effector mount **210** so that the proximal ends of the elements of the end effector have room to move when the end effector is in certain configurations. By way of example but not limitation, and looking now at FIGS. **73** and **74**, in one form of the present invention, end effector **30** comprises scissors. More particularly, in this form of the invention, end effector **30** comprises a first blade **715** having a distal end **720** and a proximal end **725**, and a second blade **730** having a distal end **735** and a proximal end **740**. First blade **715** and second blade **730** are pivotally mounted to one another and to end effector mount **210** via a pin **745**. When first blade **715** and second blade **730** are opened (i.e., to receive tissue, suture, etc. that is to be cut), proximal end **725** of first blade **715**, and proximal end **740** of second blade **730**, project laterally out of end effector mount **210** (FIG. **73**). It has been found that proximal ends **725**, **740** can present a sharp surface which can damage surrounding equipment and/or the anatomy when end effector **30** is used in a surgical procedure, particularly when end effector **30** is rotated at a surgical site while blades **715**, **730** are in their opened position. To eliminate this issue, a cover **750** may be provided which covers the proximal portion of end effector mount **210**. As a result, the proximal ends **725**, **740** of blades **715**, **730** remain covered even when blades **715**, **730** are in their open position, whereby to prevent damage to the anatomy or other surgical equipment. In one preferred form of the invention, cover **750** is formed out of an electrically-insulating material so that cover **750** also provides electrical insulation. This can be advantageous where end effector **30** comprises monopolar scissors, etc.

7.6 Enhanced Handle and Trigger Ergonomics

As discussed above, in one preferred form of the present invention, trigger **415** (FIG. **25**) is pivotally mounted to handle **10** and may be selectively pulled by a user in order to selectively actuate end effector **30**. For the purposes of illustration, trigger **415** is shown in FIG. **25** as a traditional "pistol type" trigger, and handle **10** is shown as comprising a traditional "pistol type" grip.

However, it has been found that it is sometimes desirable to provide additional stabilization elements on handle **10** (e.g., to facilitate single-handed use of medical instrument **5**) and/or to provide a trigger having a longer throw (i.e., an increased arc of movement) for providing better leverage.

To these ends, and looking now at FIGS. **75** and **76**, in one form of the invention, a handle **10** comprises a "pinky" stabilizer ring **755** for receiving the "pinky" finger of a user and a "shepard's hook"-type trigger **760** for providing greater leverage and superior ergonomics to a user. This construction facilitates a better single-handed grip of handle **10** by a user and also allows a user to easily move trigger **415** proximally or distally (e.g., to pull or push pull wire **230** in order to selectively close/open the jaws of a grasper, etc.)

7.7 Monopolar Electrical Current Delivery

In some circumstances it is desirable to be able to deliver monopolar electrical power to end effector **30**. By way of example but not limitation, where end effector **30** comprises monopolar ("hot") scissors, it is necessary to transmit electrical power from handle **10**, along (or through) shaft **15**, to end effector **30**.

To that end, and looking now at FIGS. **77-80**, in one preferred form of the present invention, there is provided an electrical connection port (e.g., a "banana jack") **765** disposed on the proximal end of the grip of handle **10** for connection to an external power supply (not shown), and a wire **770** (FIG. **79**) disposed within internal cavity **280** of handle **10** for routing electrical power from electrical connection port **765** to a flat conductive spring **775** disposed within handle **10** (FIG. **80**). Flat conductive spring **775** contacts the plurality of teeth **409** disposed on roticulation key **405**, whereby to make electrical contact with roticulation key **405** and hence HHS coil **225** and/or pull wire **230** via roticulation key **405**. It should be appreciated that, with this form of the invention, ball nose spring plunger **410** is preferably omitted (i.e., it is replaced by flat conductive spring **775**). In addition, with this form of the invention, roticulation key **405** (and teeth **409** of roticulation key **405**) are formed out of an electrically-conductive material (e.g., metal), as is long laser-cut hypotube **180**, rotation connector **200** and end effector mount **210**. As a result, electrical power can pass from an external power supply (not shown) to electrical connection port **765**, along wire **770** to flat conductive spring **775**, from conductive spring **775** to roticulation key **405**, and then to HHS coil **225** (and also to pull wire **230**), along HHS coil **225** (and pull wire **230**) through flexible proximal portion **20** of shaft **15**, through sleeve (or crimp) **265** to long laser-cut hypotube **180**, along long laser-cut hypotube **180** (and pull wire **230**) through distal articulating portion **25** of shaft **15**, to rotation connector **200** and end effector mount **210**, and from end effector mount **210** to end effector **30**. In this way, monopolar power can be supplied to end effector **30**.

Modifications of the Preferred Embodiments

It should be understood that many additional changes in the details, materials, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the present invention, may be made by those skilled in the art while still remaining within the principles and scope of the invention.

What is claimed is:

1. Apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated.

2. The apparatus according to claim **1** wherein the shaft is configured such that when the articulating portion has been articulated, rotation of the rotatable element occurs without the build-up of spring energy within the shaft.

3. The apparatus according to claim **1** wherein each of the plurality of articulation cables has an articulation cable housing disposed about the articulation cable such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends.

4. The apparatus according to claim **3** wherein the articulation cable housings provide a counterforce to the flexible spine.

5. The apparatus according to claim **1** wherein the flexible portion of the shaft comprises an outer coil secured to the flexible spine.

6. The apparatus according to claim **5** wherein, when tension is applied to at least one of the plurality of articulation cables, articulation cable housings disposed about the plurality of articulation cables provide substantially all of the counterforce to the flexible spine and the outer coil provides substantially none of the counterforce to the flexible spine.

7. The apparatus according to claim **1** further comprising a rigid tube configured to rotate relative to the handle, and an outer covering secured to the rigid tube and the flexible spine, such that rotation of the rigid tube causes rotation of the outer covering which causes rotation of the flexible spine.

8. The apparatus according to claim **1** wherein the rotatable element comprises a hollow tubular structure extending distally from the handle, the hollow tubular structure being formed out of a plurality of filars which are wound and swaged together.

9. The apparatus according to claim **8** wherein the rotatable element further comprises a laser-cut hypotube secured to the hollow tubular structure, such that when the hollow tubular structure is rotated, the laser-cut hypotube is also rotated.

10. The apparatus according to claim **1** wherein the actuation element comprises a pull wire.

11. The apparatus according to claim **1** wherein the end effector comprises one from the group consisting of: graspers, injection needles, scissors, hot snares, monopolar probes, hemostasis clips, bipolar forceps, suction tubes, single-fire or multi-fire closure devices such as staplers and tackers, dissector forceps, retrieval baskets, and monopolar scissors.

12. The apparatus according to claim **1** wherein the proximal end of the shaft further comprises a rigid portion, and wherein the apparatus further comprises a tool support mounted to a patient support, the tool support comprising an opening for receiving the rigid portion.

13. A method for performing a minimally-invasive procedure, the method comprising:

obtaining apparatus for performing a minimally-invasive procedure, the apparatus comprising:

a tool comprising:

a shaft having a distal end and a proximal end;

a handle attached to the proximal end of the shaft; and

an end effector attached to the distal end of the shaft;

wherein the shaft comprises a flexible portion extending distally from the proximal end of the shaft, and an articulating portion extending proximally from the distal end of the shaft, and wherein the articulating portion comprises a flexible spine;

wherein a plurality of articulation cables extend through the shaft from the handle to the flexible spine, such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends;

wherein a rotatable element extends through the shaft from the handle to the end effector, such that when the rotatable element is rotated, the end effector rotates; and

wherein an actuation element extends through the shaft from the handle to the end effector, such that when the actuation element is moved, the end effector is actuated; and

using the apparatus to perform a minimally-invasive procedure.

14. The method according to claim **13** wherein the shaft is configured such that when the articulating portion has been articulated, rotation of the rotatable element occurs without the build-up of spring energy within the shaft.

15. The method according to claim **13** wherein each of the plurality of articulation cables has an articulation cable housing disposed about the articulation cable such that when tension is applied to at least one of the plurality of articulation cables, the flexible spine bends.

16. The method according to claim **15** wherein the articulation cable housings provide a counterforce to the flexible spine.

17. The method according to claim **13** wherein the flexible portion of the shaft comprises an outer coil secured to the flexible spine.

18. The method according to claim **17** wherein, when tension is applied to at least one of the plurality of articulation cables, articulation cable housings disposed about the plurality of articulation cables provide substantially all of the counterforce to the flexible spine and the outer coil provides substantially none of the counterforce to the flexible spine.

19. The method according to claim **13** wherein the apparatus further comprises a rigid tube configured to rotate relative to the handle, and an outer covering secured to the rigid tube and the flexible spine, such that rotation of the rigid tube causes rotation of the outer covering which causes rotation of the flexible spine.

20. The method according to claim **13** wherein the rotatable element comprises a hollow tubular structure extending distally from the handle, the hollow tubular structure being formed out of a plurality of filars which are wound and swaged together.

21. The method according to claim **20** wherein the rotatable element further comprises a laser-cut hypotube secured to the hollow tubular structure, such that when the hollow tubular structure is rotated, the laser-cut hypotube is also rotated.

22. The method according to claim **13** wherein the actuation element comprises a pull wire.

23. The method according to claim **13** wherein the end effector comprises one from the group consisting of: graspers, injection needles, scissors, hot snares, monopolar probes, hemostasis clips, bipolar forceps, suction tubes, single-fire or multi-fire closure devices such as staplers and tackers, dissector forceps, retrieval baskets, and monopolar scissors.

24. The method according to claim **13** wherein the proximal end of the shaft further comprises a rigid portion, and wherein the apparatus further comprises a tool support mounted to a patient support, the tool support comprising an opening for receiving the rigid portion.

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